E1075

ARTICLE I.

ANALYSIS AND EXTRACTS

OF

كتاب ميزان الحكمة

BOOK OF THE BALANCE OF WISDOM,

AN ARABIC WORK ON THE WATER-BALANCE,

WRITTEN BY 'AL-KHÂZINÎ IN THE TWELFTH CENTURY.

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Presented to the Society October 29, 1857.

[Our correspondent having communicated his paper to us in the French language, accompanied with the extracts in the original Arabic, we have taken the liberty to put it into English, and have in fact re-translated the extracts rather than give them through the medium of the French version. M. Khanikoff's own notes are printed on the pages to which they refer. To these we have added others, relating to the original text and its contents, which are distinguished by letters and numerals, and will be found at the end of the article.—Comm. of Publ.]

The scantiness of the data which we possess for appreciating the results arrived at by the ancient civilizations which preceded that of Greece and Rome, renders it impossible for us to form any probable conjecture respecting the development which our present knowledge might have attained, if the tradition of the discoveries made by the past in the domain of science had been transmitted without interruption, from generation to generation, down to the present time. But the history of the sciences presents to us, in my opinion, an incontestable fact of deep significance: the rediscovery, namely, in modern times, of truths laboriously established of old; and this fact is of itself enough to indicate the necessity of searching carefully in the scientific heritage of the past after all that it may be able to furnish us for the increase of our actual knowledge; for a double discov-

ery, necessarily requiring a double effort of human intellect, is an evident waste of that creative force which causes the advance of humanity in the glorious path of civilization. Modern orientalists are beginning to feel deeply the justice and the importance of the counsel given them by the author of the Mécanique Céleste, who, in his Compendium of the History of Astronomy, while persuading them to extract from the numerous oriental manuscripts preserved in our libraries whatever they contain that is of value to this science, remarks that "the grand variations in the theory of the system of the world are not less interesting than the revolutions of empires;" and the labors of MM. Chézy, Stanislas Julien, Am. Sédillot, Woepcke, Bochart, Sprengel, Moreley, Dorn, Clément-Mullet, and others, have enriched with a mass of new and instructive facts our knowledge respecting the state of the sciences in the Orient. Notwithstanding this, however, it must be granted that M. Clément-Mullet was perfectly justified in saying, as he has done in an article on the Arachnids, published in the Journal Asiatique,* that researches into the physical sciences of the Orientals have been entirely, or almost entirely, neglected; and it is only necessary to read the eloquent pages in which the author of the Cosmos estimates the influence of the Arab element upon European civilization, to be convinced of the scantiness of our information as to the condition of physical science among the Arabs; for that illustrious representative of modern civilization, after having shown that the Arabs had raised themselves to the third step in the progressive knowledge of physical facts, a step entirely unknown to the ancients, that, namely, of experimentation, concludes that,† "as instances of the progress which physical science owes to the Arabs, one can only mention the labors of Alhazen respecting the refraction of light, derived perhaps in part from the Optics of Ptolemy, and the discovery and first application of the pendulum as a measure of time, by the great astronomer Ebn-Yunis."

All this leads me to suppose that men of science will be interested to have their attention called to a work of the twelfth century, written in Arabic, which treats exclusively of the balance, and of the results arrived at by the help of that instrument, which has given to modern science so many beautiful discoveries. I hesitated for some time whether to offer a pure and simple translation of this work, or a detailed analysis of its contents, presenting in full only those passages which contain remarkable matter, worthy of being cited. Finally, taking into consideration the numerous repetitions, the superfluity of detail, and even

* Number for Aug.—Sept., 1854, 5me Série, iv. 214, etc.
† Kosmos, ii. 258 (original edition).

the obscurity of exposition, of matters which, thanks to the progress of science, have become for us elementary, and which, if presented in the little attractive form of the original text, would tend rather to conceal than to develop the interesting facts which it contains, I have decided to translate, in full, only the preface and introduction of the work, its exposition of the principles of centres of gravity, and its researches into the specific gravities of metals, precious stones, and liquids, and to limit myself, beyond this, to citing the words of the author as *pièces justificatives*, to show whether I have fully apprehended the sense of his reasonings.

I have had at my disposal only a single manuscript copy of this work, which moreover lacks a few leaves in the middle and at the end, so that it has been impossible to determine its age: to judge from the chirography, however, it is quite ancient, and the absence of diacritical points sufficiently indicates that it is a work of the scribes of Ispahan, who have the bad habit of omitting these points, so essential to the correct reading of oriental texts. The original of each extract, whether longer or shorter, will be found accompanying its translation. It only remains for me to say that I have been scrupulous to render as faithfully as possible the text of my author, wherever I have cited from him; in the cases where I have had to fill out the ellipses so common in Arabic, I have marked the words added by placing them in brackets.

The work commences thus:

بسم الله الرحمن الرحيم

الحمد لله الذى لا اله الا هو الحكم الحق العدل والصلوة على جميع انبيائه
ورسله الذين بعثهم الى عباده للعدل وخصص نبينا محمد المصطفى صلى
الله عليه وآله وسلم بالشريعة السمحة العدل   وبعد فان العدل نظام
الفضائل جملة وملاك الخيرات اجمع لأن الفضيلة التامة هى الحكمة وهى
فى شقى العلم والعمل وشطرى الدين والدنيا علم تامّ وفعل محكم والعدل

In the name of God, the Compassionate, the Merciful.

Praise be to God, beside whom there is no deity, the Wise, the True, the Just! and may the blessing of God rest upon all His prophets and ambassadors, whom He has sent to His servants in order to justice, singling out our Prophet Muḥammad, the Elect, to be the bearer of the law mild in righteousness!

Now, then, to our subject. Justice is the stay of all virtues, and the support of all excellencies. For perfect virtue, which is wisdom in its two parts, knowledge and action, and in its two aspects, religion and the

مجمع بينهما وملتقى كماليها به ينال قاصية كل مجد وبسببه يحاز قصب
السبق فى كل خير ولاعتلائه ذروة الكمال عرف البارى تعالى نفسه الى
خلص عباده باسم العدل وبنوره صار العلم مستوفيا. اقسام الكمال والتمام
ومستوليا على الامد الاقصى فى النظام واليه الاشارة بقوله عليه السلم
بالعدل قامت السموات والارض ولما اختص العدل بهذه الرتبة العلية
والمنزلة السنية افاض الله عليه خلع الرضاء والمحبة واحبه الى قلوب عباده
جملة حتى صار مالوف الطباع ومطلوب النفوس وتراها متشوقة الى
تجربته[a] بمجهود وسعهم فان عاقهم عنه عايق او صرفهم الى ضده صارف
يجدون فى انفسهم اعترافا به واقرارا بحقيقته حتى ان الجاير يستحسن
عدل غيره ولذلك ترى النفوس تتألم عن كل ما كان مركبا ليس على
نظام مستقيم فتكره العرج والعور وتتشأم به وللوفاء بقضيته[b] ما جعل الله
تعالى اعضاء الانسان الواقعة فى الاطراف زوجين اثنين وفى الاوساط واحدا
اوحدا ثم اهاب بهم الى سلوك سبل السعادة باستعمال العدل وملازمة

course of the world, consists of perfect knowledge and assured action; and justice brings the two [requisites] together. It is the confluence of the two perfections of that virtue, the means of reaching the limits of all greatness, and the cause of securing the prize* in all excellence. In order to place justice on the pinnacle of perfection, the Supreme Creator made Himself known to the Choicest of His servants under the name of the Just; and it was by the light of justice that the world became complete and perfected, and was brought to perfect order — to which there is allusion in the words of the Blessed: "by justice were the heavens and the earth established;" and, having appropriated to justice this elevated rank and lofty place, God has lavished upon it the robes of complacency and love, and made it an object of love to the hearts of all His servants; so that human nature is fond of it, and the souls of men yearn after it, and may be seen to covet the experience of it, using all diligence to secure it. If any thing happens to divert men from it, or to incline them to its opposite, still they find within themselves a recognition of it and a confirmation of its real nature; so that the tyrant commends the justice of others. For this reason, also, one sees the souls of men pained at any composition of parts which is not symmetrical, and so abhorring lameness and blindness, and auguring ill therefrom. Moreover, in order to the preservation of the empire of justice, the Supreme

* قصب السبق i. e. reed of precedence. By this name is designated a lance planted in the middle of a plain, where horse-races are held, and which the leader in the race seizes in passing.

الاستقامة على ما قال تعالى واقسطوا ان الله يحب المقسطين وقال ان
الذين قالوا ربنا الله ثم استقاموا ارادة للخير بهم وافاضة للرحمة عليهم
وجعله حكما بين الخليقة ورضى بينهم على الحقيقة حتى لا يعبر احد
جسر النجاة الا بجواز من الاستقامة فى العمل ولا يسكن احد حريم
السعادة الا بتوقيع من العدل فى العلم والعدل فى العلم هو تحقق المعلوم
على وجهه بطريقه مصونا عن وصمة الشك والاشتباه والعدل فى العمل نوعان
الاول العمل وهو تهذيب الاخلاق ورعاية المساواة بين قوى النفس
والقيام عليها بحسن السياسة على ما قيل اعدل الناس من انصف عقله
من هواه ومن تمامه بث النصفة بين دونه وكف اذاه عن غيره حتى
يأمن الناس شره الثانى والمعاملة وهى رعاية الانصاف بين نفسه ومعاملته
فى اداء حقوقهم واستيداءها منهم والعدل هو القوام لامر الدين والدنيا
والركن لسعادة الاخرة والاولى فمن تمسك به او بشعبة من شعبه فقد

God has made the side-members of man's body in pairs, and its middle members single; and He calls men to pursue the paths of felicity by the practice of justice, and adherence to uprightness, according to the divine words: "and do justly—verily, God loves them who do justly,"* and again: "as for them who say 'our Lord is God,' and are upright"†—wishing to do them good, and lavishing mercy upon them. God has even set up justice as the criterion of judgment between His creatures, being content with equity; so that no one will pass the bridge of salvation without a certificate of uprightness in action, nor repose in the paradise of felicity without a diploma of justice in knowledge.

Justice in knowledge is the verification of the object of knowledge in accordance with its scope, in the way appropriate to it, kept clear of the defect of doubt and uncertainty. Justice in action is two-fold: 1. self-government, which is the harmonizing of the natural endowments, the maintenance of equilibrium between the powers of the soul, and the bringing of them under beautiful control—agreeably to the saying: "the most just of men is he who lets his reason arbitrate for his desire;" and it is a part of the perfection of such a man that he dispenses justice among those inferior to himself, and wards off from others any injury which he has experienced, so that men are secure as to his doing evil; 2. control over others, which consists in the maintenance of moderation within one's self, together with a power of constraint, in respect to the performance of obligations to men, and the requiring of that performance on their part.

* Kur. xlix. 9. † Kur. xlvi. 12.

استمسك بالعروة الوثقى لا انفصام لها ولعناية رحمة الله تعالى برعاية
مصالح عباده وتقويمهم على نهج سداده اراد ان يبقى العدل بينهم
الى يوم الدين بلا نهاية لا يخلق جديده مرور الازمنة والاحقاب وعلم
انهم ظالموا انفسهم باتباعهم مواجب طباعهم والزمهم كلمة التقوى وكانوا
احقّ بها واهلها وحفظ عليهم بشمول رأفته وسعة رحمته نظام الخير
بان بعث فيهم حكام عدل يحفظون عليهم العدل ولا يفترون وهم ثلاثة
بحسب اقسامه فالاول كتاب الله العزيز الذى لا يأتيه الباطل من بين
يديه ولا من خلفه وهو القانون الاعظم المرجوع اليه فى الفروع والاصول
والمحكوم به بين الفاضل والمفضول ويتبعه سنّة النبى عليه السلم
والثانى الأيمة المهتدون والعلماء الراسخون المتنصبون لحلّ الشبه
ورفع الشكوك الذين هم نواب الرسول وخلفايه فى كل عصر وزمان وهم الحماة
لحوزة الدين والهداة للخلق الى سبل النجاة عند اعتراض الشكوك
والشبهات ومنهم الوالى العدل المشار اليه بقوله عليه السلم السلطان
ظلّ الله تعالى فى ارضه يأوى اليه كل مظلوم والحاكم الثالث الميزان

Justice is the support of both religion and the course of the world, and the stay of future as well as present felicity; so that whoever takes hold of it, or of one of its branches, takes hold of a strong handle to which there is no breaking. Furthermore, because the mercy of the Supreme God intended to secure the rewards of virtue to His servants, and to establish them in the open way of His rectitude, He willed that justice should abide among them to the last day, uninterrupted, and unimpaired by the lapse of times and ages. Knowing that men would injure one another by compliance with the requirements of their natural impulses, He gave them self-command, as an inherent prerogative of their being—which they are naturally capable of and fitted for—and, in the amplitude of His mercy, and the breadth of His compassion, has provided for them, with constant goodness, by raising up among them just judges, their never-failing securities for justice. Of these there are three, answering to the several divisions of justice: 1. the glorious Book of God, which, from beginning to end, is without any admixture of error, is the supreme canon, to which both legal rules and doctrinal principles refer back, the arbiter between the Supereminent and the subject creature, to which the tradition of the Blessed Prophet is the sequel; 2. the guided leaders and established doctors, set up in order to the dissipation of uncertainties and the removal of doubts, who are the vicars of the Prophet, and his substitutes, in every age and time, who protect the way of religion, and guide men into the paths of

الذى هو لسان العدل وترجمة الانصاف بين العامّة والخاصّة والحكم
العدل فى قضيته الذى رضى بقضائه الفصل كل بر وفاجر ومنصف ومتعسف
العالم باستقامته لفصل خصوماتهم الحافظ عليهم النظام والعدل فى
تصرفاتهم ومعاملاتهم الذى جعله الله قرينة قرانه ونظمها فى سلك امتنانه
فقال تعالى الله الذى انزل الكتاب بالحق والميزان وجعل المنة فى وضع
الميزان مقرونة بالمنة فى رفع السماء فقال عز وجل والسماء رفعها ووضع الميزان
ان لا تطغوا فى الميزان واقيموا الوزن بالقسط ولا تخسروا الميزان وقال الله
تعالى وزنوا بالقسطاس المستقيم وهو فى الحقيقة نور من انوار الله تعالى
افاض على عباده من كمال عدله ليفصلوا به بين الحق والباطل والمستقيم
والمائل لان حقيقة النور ما يظهر بنفسه فيبصر ويظهر غيره فيبصر به والميزان
هو الذى يعرف منه استقامته وانحرافه ويعرف منه استقامة غيره وميله

felicity, when attacked by doubts and uncertainties; of whom is the just ruler alluded to in the words of the Blessed: "the Sulṭân is the shadow of the Supreme God, upon His earth, the refuge of every one injured, and the judge;" 3. the balance, which is the tongue of justice, the article of mediation between the commonalty and the great; the criterion of just judgment, which with its final decision satisfies all the good and wicked, just-doers and doers of iniquity; the standard, by its rectitude, for the settlement of men's altercations; the security of order and justice among men, in respect to things which are left to them and committed to their disposal; made by God the associate of His Ḳurân, which He joins on to the pearl-strings of His beneficence, so that the Supreme says: "God who hath sent down the True Book and the balance,"* and connects the benefit of the institution of the balance with that of the raising of the heavens, in the divine words: "and as for the heavens, He hath raised them; and He hath instituted the balance; transgress not respecting the balance, do justice in weighing, and diminish not with the balance."† The Supreme God also says: "weigh with an even balance."‡ Indeed, the balance is one of the Supreme God's lights, which He has bountifully bestowed upon His servants, out of the perfection of His justice, in order that they may thereby distinguish between the true and the false, the right and the wrong. For the essence of light is its being manifest of itself, and so seen, and that it makes other things manifest, and is thus seen by; while the balance is an instrument which, of itself, declares its own evenness or deflection, and is the means of recognizing the rectitude or deviation therefrom of other things. It is on account of the great power of the balance, and its binding authority, that God has magnified and exalted

* Ḳur. xlii. 16. † Ḳur. lv. 6, 7, 8. ‡ Ḳur. xvii. 37.

وشدة ظهوره ووكادة امره ما عظم الله شأنه وفخم امره حيث سلكه به كتابه والسيف فقال تعالى وانزلنا معهم الكتاب والميزان ليقوم الناس بالقسط وانزلنا الحديد فيه بأس شديد فاذا الميزان هو احد الاركان الثلاثة التى بها يقوم العدل الذى به قوام العالم وبهذه المناسبة سمى العدل ميزان الله بين عباده وبما هو انموذج له نفى الظلم عن حكمه يوم الدين فقال تعالى افلا تظلم نفس شيا فمن اوتى الميزان بالقسط فقد اوتى خيرا كثيرا وما يذكر الا اولو الالباب .

فصل

فى تعداد فوايد ميزان الحكمة ومنافعه ✿ قال الخازنى بعد ذكر الميزان المطلق ميزان الحكمة الذى اشنبطته الافكار واكملته التجربة والامتحان عظيم الشأن لما فيه من المنافع ونيابته عن حذّاق الصناع منها الاولى[d] دقّة الوزن يظهر فيه تفاوت مثقال او حبّة وان كانت زنته بجميع اعصابه الف مثقال هذا اذا صانعه دقيق اليد لطيف الصنعة عالما بها الثانية يتحقق به

it to such a degree as to rank it with His Book and the sword, in the divine words: "and we have sent down, with them, the Book; and the balance, in order that men may do justice; and we have sent down the cutting blade, which has exceeding force."* So, then, the balance is one of the three supports of that justice by which the world stands; and justice is called "God's balance among His servants," both on account of this relationship of the balance thereto, and because it typifies the justice of the last day, clear of all injustice in its sentence, which is signified by the words of the Supreme God: "shall not, then, a soul be wronged at all?"† and "he to whom the balance with just measure shall be given, will have much good done to him; and none are mindful thereof, save those who have hearts."‡

Sect. 1. *Enumeration of the Advantages and Uses of the Balance of Wisdom.*

Says 'al-Khâzinî, after speaking of the balance in general,—The balance of wisdom is something worked out by human intellect, and perfected by experiment and trial, of great importance on account of its advantages, and because it supplies the place of ingenious mechanicians. Among these [advantages] are: 1. exactness in weighing: this balance shows variation to the extent of a mithkâl, or of a grain, although the entire weight is a thousand mithkâls, provided the maker has a delicate hand, attends to the minute details of the mechanism, and understands it;

* Ḳur. lvii. 25.

† Ḳur. xxi. 48, with افلا for فلا.

‡ Ḳur. ii. 272, altered.

صميم الفلزّ من مغشوشه احاد احاد منها من غير تخليص والثالثة يعرف
به ما فى الجرم الممتزج بجرم اخر من الفلزات مثنى مثنى من غير ان
يفكّ بعضها من بعض بسبك او تخليص او تغيير هيئة باسرع وقت واهون
سعى والرابعة يعرف به فضل وزن احد الفلزين على الاخر فى الماء اذا استوى
وزنهما فى الهواء وعكسه فى الهواء اذا استوى وزنهما فى الماء ونسب حجم
بعضها الى بعض من وزنهما فيهما والخامسة يعرف به جوهر الشئ الموزون
من زنته بخلاف ساير الموازين لانها لا تفصل بين الذهب والحجر الموزونين
والسادسة اذ حوّلت ابعاد الكفات عن المعلاق الى نسبة مفروضة نحو السعر
والمسعّر والسبعة والعشرة للدراهم والدنانير يعرف اشياء عجيبة نحو قيم
الاشياء من غير واسطة الصنجات يشار الى الجوهر الذى تقوم ذاته ويبين
ما يساويه حكما ومن مسايل الصرف والمعاملات ودار الضرب فى تغير العيار

2. that it distinguishes pure metal from its counterfeit, each being recognized by itself, without any refining; 3. that it leads to a knowledge of the constituents of a metallic body composed of any two metals, without separation of one from another, either by melting, or refining, or change of form, and that in the shortest time and with the least trouble; 4. that it shows the superiority in weight of one of two metals over the other in water, when their weight in air is the same; and reversely, in air, when their weight in water is the same; and the relations of one metal to another in volume, dependent on the weight of the two [compared] in the two media; 5. that it makes the substance of the thing weighed to be known by its weight—differing in this from other balances, for they do not distinguish gold from stone, as being the two things weighed; 6. that, when one varies the distances of the bowls from the means of suspension in a determined ratio, as, for example, in the ratio of impost to the value of the article charged therewith, or the ratio of seven to ten, which subsists between dirhams and dînârs,* surprising things are ascertained relative to values, without resort to counterpoises—[for instance,] essential substance is indicated, and the [mere] similitude of a thing is decisively distinguished; and theorems relative to exchange and legal tenders and the mint, touching the variation of standard value, and certain theorems of curious interest, are made clear; 7. the gain above all others—that it enables one to know what is a genuine precious stone,

* Impost, السعر, in this passage, denotes the valuation in units of money of a unity of provisions of a given sort; and this unity is the thing charged with the impost, المسعّر. Hence the relation of one to the other must be numerical, like that between dirhams and dînârs, which are proportioned to one another as 7 to 10. This explanation is derived from the second chapter of the eighth lecture of our author's work, which is not of sufficient importance to be translated.

ومسايل غريبة والسابعة هو الغرض الاقصى فيه وهو معرفة حقيّة الجواهر
الحجرية كالياقوت واللعل والزمرد واللولو لانه الحكم الحق بينها وبين اشباهها
وملوناتها المغشوشة فهذه المعانى دعتنا الى النظر فيه وجمع هذا الكتاب
بعون الله وحسن توفيقه

الفصل الثانى

فى المدخل فيه ۞ وهذا الميزان العدل مبنى على البراهين الهندسيّة
ومستنبط من العلل الطبيعيّة من وجهين احدهما من مراكز الاثقال الذى
هو اجلّ اقسام العلوم الرياضية واشرفها وهو معرفة اوزان الاثقال المختلفة
المقادير بتفاوت ابعاد ما يقاومها وعليه مبنى القفّان والثانى معرفة اوزان
الاثقال المختلفة المقادير بتفاوت اجرام رطوبات يغاص فيها الموزون دقة
وخثورا وعليها مبنى ميزان الحكمة واشار القدماء الى التنبيه عليهما اشارة
على ما هو دأبهم فى اخراج الخبايا واظهار الخفايا من الحكم الجليلة والعلوم
النفيسة فرأينا ان نجمع من هذا الفنّ ما استفدنا من تصانيفهم والذين
يلونهم من الحكماء مضموما الى ما سمح الخاطر به بعون الله وتوفيقه

such as a hyacinth, or ruby, or emerald, or fine pearl; for it truly discriminates between these and their imitations, or similitudes in color, made to deceive.

These views have led us to the consideration of the balance of wisdom, and to the composition of this book, with the help of God and His fair aid.

Sec. 2. Theory of the Balance of Wisdom.

This just balance is founded upon geometrical demonstrations, and deduced from physical causes, in two points of view: 1. as it implies centres of gravity, which constitute the most elevated and noble department of the exact sciences, namely, the knowledge that the weights of heavy bodies vary according to difference of distance from a point in common—the foundation of the steelyard; 2. as it implies a knowledge that the weights of heavy bodies vary according to difference in rarity or density of the liquids in which the body weighed is immersed—the foundation of the balance of wisdom.

To these two principles the ancients directed attention in a vague way after their manner, which was to bring out things abstruse, and to declare dark things, in relation to the great philosophies and the precious sciences. We have, therefore, seen fit to bring together, on this subject, whatever useful suggestions their works, and the works of later philosophers have afforded us, in connection with those discoveries which our own meditation, with the help of God and His aid, has yielded.

الفصل الثالث

فى مبادیها ۞ فنقول ان لكل صناعة مبادى يبتنى عليها ومصادرات يستند اليها من جهلها خرج عن طبقة من يخاطب فيها وتفنّن تلك المبادى والمصادرات الى ثلثة فنون الاول ان تكون حاصلة من اول الولادة والنشو عن احساس واحد او احساسات كثيرة ولم يتعمّد لها وهى التى تسمّى الاوايل والعلوم العامّية المتعارفة[e] الثانى ان تكون مبرهنة فى علوم اخر والثالث ان تكون مستفادة عن التجربة والمزاولة وهذه الصناعة التى اردنا الشروع فيها لما كانت مركبة من صناعتى الهندسية والطبيعية[f] جامعة من مقولتى كم وكيف وقد كانت لكل واحد من الصناعتين المبادى المذكورة فبالواجب صارت الاقسام الثلاثة من المبادى حاصلة لها فلا يتمّ معرفتها به دون استحكامها وبعض العلوم المتعارفة لهذه الصناعة لما قد بلغت من وضوحها الى حيث لا يحتاج الى مصادرتها فى الكتب فضربنا صفحا ولم نسلك هذا المسلك فى بعضها الذى لم يبلغ فى الوضوح المبلغ الذى ذكرناه[g] عند الحاجة له[h] واما المبادى التى تحصل بعد

Sec. 3. Fundamental Principles of the Art of Constructing this Balance.

Every art, we say, has its fundamental principles, upon which it is based, and its preliminaries to rest upon, which one who would discuss it must not be ignorant of. These fundamental principles and preliminaries class themselves under three heads: 1. those which rise up [in the mind] from early childhood and youth, after one sensation or several sensations, spontaneously; which are called first principles, and common familiar perceptions; 2. demonstrated principles, belonging to other departments of knowledge; 3. those which are obtained by experiment and elaborate contrivance. Now as this art which we propose to investigate involves both geometrical and physical art, uniting as it does the consideration of quantity and quality; and as to each of these two arts pertain the fundamental principles mentioned, it has itself, necessarily, such fundamental principles; so that one cannot possess a thorough knowledge of it, without being well grounded in them. But inasmuch as some of the familiar perceptions relative to this art are so perfectly evident that it is useless to draw upon them in books, we leave them unnoticed; pursuing a different course in respect to certain first principles not perfectly evident, which we shall speak of as there is occasion. As for those derivative fundamental principles, obtained by experiment and ocular proof, and likewise, as to demonstrated principles belonging

التجربة والمشاهدة وكذلك التى برهن عليها فى علوم اخر قد نبّهنا على
مقدار الكفاية منها اشارة ورمزا

الفصل الرابع

فى وضع ميزان الماء واسماء المتكلمين فيه وطبقاتهم واصناف صور الموازين
المستعملة فيه واشكالها واسمائها ✿ قيل انه كان سبب فكرة الحكماء الى
وضع هذا الميزان والداعى اليه هو كتاب مانالاوس الى دوماطيانوس[i] قال
ايها الملك ان ايارون ملك سقلية اتى يوما باكليل عظيم القدر اهدى اليه
من بعض النواحى وكان منقن الصنعة محكم العمل وانه عرض لايارون[j] ان
هذا الاكليل ليس بذهب خالص لكنّه مشوب بفضّة ففحص عن امر الاكليل
فتبيّن انه من ذهب وفضّة فاحبّ معرفة مقدار ما فيه من كل واحد منهما
وكره كسر الاكليل لما كان عليه من اتقان الصنعة فسأل ذوى الهندسة والحيل
عن ذلك فلم يوجد فيهم احد كانت عنده الحيلة فى ذلك الا الارشميدس
المهندس وكان فى صحبة ايارون[k] فاستنبط حيلة يتهيّأ بها ان يعلم ايارون[l]
الملك كم فى الاكليل من الذهب وكم فيه من الفضة والاكليل ثابت على

to other sciences, we shall call them up so far as may be necessary, in the way of allusion and passing notice.

Sect. 4. *Institution of the Water-balance; Names of those who have discussed it, in the order of their succession; and Specific Forms of Balances used in Water, with their Shapes and Names.*

It is said that the [Greek] philosophers were first led to think of setting up this balance, and moved thereto, by the book of Menelaus addressed to Domitian, in which he says: "O King, there was brought one day to Hiero King of Sicily a crown of great price, presented to him on the part of several provinces, which was strongly made and of solid workmanship. Now it occurred to Hiero that this crown was not of pure gold, but alloyed with some silver; so he inquired into the matter of the crown, and clearly made out that it was composed of gold and silver together. He therefore wished to ascertain the proportion of each metal contained in it; while at the same time he was averse to breaking the crown, on account of its solid workmanship. So he questioned the geometricians and mechanicians on the subject. But no one sufficiently skillful was found among them, except Archimedes the geometrician, one of the courtiers of Hiero. Accordingly, he devised a piece of mechanism which, by delicate contrivance, enabled him to inform king Hiero how much gold and how much silver was in the crown, while yet it retained its form." That was before the time of Alexander. Afterwards, Menelaus

هيئته بحيلة لطيفة وكان هو قبل الاسكندر ثم نظر فيه مانالاوس واستخرج
فيه طرقا كلّيّة حسابية وله فيه رسالة وكان بعد الاسكندر باربعماة سنة
ثم نظر فيه من المتأخرين في ايام المامون سند بن علي ويوحنا بن يوسف
واحمد بن الفضل المساح وفي ايام السامانية محمد بن زكريا الرازي وعمل
فيه رسالة ذكرها في كتاب الاثنى عشر وسماه الميزان الطبيعي وفي ايام الدولة
الديلمية كان ينظر فيه ابن العميد والفيلسوف ابن[m] سينا وميّزان الجرم
الممتزج علما وحكما ولم يصنّفا فيه تصنيفا وفي ايام آل ناصر الدين نظر فيه
ابو الريحان ورصد فيه نسب اجرام الفلزات والجواهر واستخرج لتمييز
بعضها عن بعض حكما وعلما لا سبكا وتخليصا طرقا حسابية ومن هولاء
المذكورين من زاد فيه كفة ثالثة مزدوجة مع احدى الكفتين لمعرفة زنة
مقدار شول احدى الكفتين في الماء وسهّلوا بتلك الزيادة بعض التسهيل
ثم في هذه الدولة القاهرة ثبتها الله تعالى نظر فيه الامام ابو حفص عمر
الخيامي وحقّق القول فيه وبرهن على صحّة رصده والعمل به لماء معيّن
دون ميزان معلم وكان معاصره الامام ابو حاتم المظفر بن اسمعيل الاسفزاري[n]

[himself] thought about the water-balance, and brought out certain universal arithmetical methods to be applied to it; and there exists a treatise by him on the subject. It was then four hundred years after Alexander. Subsequently, in the days of Mâmûn, the water-balance was taken into consideration by the modern philosophers Sand Bin 'Alî, Yûḥannâ Bin Yûsif and 'Aḥmad Bin 'al-Fadhl the surveyor; and in the days of the Sâmânide dynasty, by Muḥammad Bin Zakarîyâ of Rai, who composed a treatise on the subject, which he speaks of in his Book of the Eleven, and named this balance "the physical balance;" and in the days of the Dailamite dynasty, by 'Ibn 'al-'Amîd and the philosopher 'Ibn-Sînâ, both of whom distinguished [the components of] a compound body scientifically and exactly, but composed no work on the subject; and in the days of the house of Nâṣir 'ad-Dîn, by 'Abu-r-Raiḥân, who took observations on the relations of [different] metallic bodies and precious stones, one to another, as indicated by this balance, and carried his deductions so far as to distinguish one from another [in a compound], exactly and scientifically, without melting or refining, by arithmetical methods.

Some one of the philosophers who have been mentioned added to the balance a third bowl, connected with one of the two bowls, in order to ascertain the measure, in weight, of the rising of one of the two bowls in the water: and by that addition somewhat facilitated operations. Still later, under the victorious dynasty now reigning—may the Supreme God establish it!—the water-balance was taken up by the eminent teacher 'Abû-Ḥafṣ 'Umar 'al-Khaiyâmî, who verified what was said of it, and

ناظرا فيه مدة احسن نظر ومتأملا في صنعته ومتأنقا في حدّته وسعي في
تسهيل العمل به على من اراده وزاد فيه منقلتين للتمييز بين جوهرين
مختلطين واشار الى امكان وجود مراكز الفلزات على عموده استقراء ورصدا
لماء معيّن الا انه لم يشير الى كميّة ابعادها عن المحور اجزاء وعددا ولا الى
شي من اعمالها سوى شكل الميزان وسماه ميزان الحكمة ومضى الى رحمة الله
تعالى قبل اتمامه وتدوينه

الفصل الخامس

في صور واشكال لميزان الماء ۞ وبعد جميعهم يقول الخازني ان الموازين
المستعملة في الماء يأتي اشكالها على ثلثة اصناف الاول صنف ذو كفتين
معهودتين يقال له الميزان المطلق الساذج وربما يزيدون شعيرات على عموده
والثاني ذو ثلاث كفات طرفيات احديها منوطة تحت الاخرى وهي
المائية يقال له الميزان الكافي او المجرّد عن المنقلة والثالث ذو خمس
كفات يقال له الميزان الجامع وهو ميزان الحكمة ثلاث منها مائية وثنتان

demonstrated the accuracy of observation upon it, and the perfection of operation with it—supposing a particular sort of water to be used—without having a marked balance. The eminent teacher ʼAbû-Ḥâtim ʼal-Muẓaffar Bin ʼIsmaʻîl of ʼIsfazâr, a cotemporary of the last named, also handled the subject, for some length of time, in the best manner possible, giving attention to the mechanism, and applying his mind to the scope of the instrument, with an endeavor to facilitate the use of it to those who might wish to employ it. He added to it two movable bowls, for distinguishing between two substances in composition; and intimated the possibility of the specific gravities of metals being [marked] upon its beam, for reading and observation, relatively to any particular sort of water. But he failed to note the distances of specific gravities from the axis, by parts divided off and numbers; nor did he show any of the operations performed with them, except as the shape of the balance implied them. It was he, too, who named it "the balance of wisdom." He passed away, to meet the mercy of the Supreme God, before perfecting it and reducing all his views on the subject to writing.

Sect. 5. Forms and Shapes of the Water-balance.

Says ʼal-Khâzinî, coming after all the above named,—Balances used in water are of three varieties of shape: 1. one with two bowls arranged in the ordinary way, called "the general simple balance"; to the beam of which are frequently added round-point numbers; 2. one with three bowls for the extreme ends, one of which is suspended below another, and

منقلتان عن موضعهما[o] وان معرفة نسب الفلزات بعضها الى بعض معينة الى اتمامه بحيلة لطيفة جزئية لكل من نظر فيه او هيّأه باثبات المراكز منها عليه لماء مخصوص مناسب فى اللطافة لماء جيحون خوارزم دون ساير المياه ويمكن بهذا الميزان ايضا للمتأمل الحاذق ان يرصد مراكز الجواهر[p] والفلزات عليه كما اذكره ان شاء الله تعالى فى اثناء الكتاب بكل ماء اتفق فى كل زمان باهون سعى واقرب مدة واسهل عمل بعون الله تعالى ويمن دولة السلطان الاعظم شاهنشاه المعظم مالك رقاب الامم سيد سلاطين العالم سلطان ارض الله ناصر دين الله حافظ عباد الله ملك بلاد الله معيّن خليفة الله معزّ الدنيا والدين كهف الاسلام والمسلمين عضد الدولة القاهرة وتاج الملّة الزاهرة ومغيث الامة الباهرة ابى الحارث سنجر بن ملكشاه بن الپارسلان برهان الدين[q] امير المومنين ادام الله سلطانه وضاعف اقتداره فان يمنه شمس العالم التى تضيئه وعدله روحه التى تحييه استمددت من انواره المشرقة

is the water-bowl; which is called "the satisfactory balance," or "the balance without movable bowl;" 3. one with five bowls, called "the comprehensive balance," the same as the balance of wisdom; three of the bowls of which are a water-bowl and two movable bowls. The knowledge of the relations of one metal to another depends upon that perfecting of the balance, by delicate contrivance, which has been accomplished by the united labors of all those who have made a study of it, or prepared it by fixing upon it [points indicating] the specific gravities of metals, relatively to a determined sort of water, similar in density to the water of the Jaihûn of Khuwârazm, exclusively of other waters.

It is also possible, however, for one who is attentive and acute, by means of this balance, to observe the specific gravities of precious stones and metals [marked] upon it, with any water agreed upon, at any time, with the least trouble, at the shortest notice, and with the greatest facility of operation; as I shall set forth in the course of this book, with the help of the Supreme God, and the felicity of the imperial power of the most magnificent Sulṭân, the exalted Shâh of Shâhs, the king of subject nations, the chief of the Sulṭâns of the world, the Sulṭân of God's earth, the protector of the religion of God, the guardian of the servants of God, the king of the provinces of God, designated as God's Khalîf, the glory of the course of the world and of religion, the shelter of Islamism and of Muslims, the arm of victorious power, the crown of the illustrious creed, and the helper of the eminent religion, 'Abû-l-Ḥârith Sanjar Bin Mâlikshâh Bin 'Alpârslan, Argument for the Faith, Prince of the Believers—may God perpetuate his reign, and double his power! For his felicity is the illuminating sun of the world, and his justice its vivifying breath.

فى الافاق فتهدّيت بها الى ما فى قوة هذا العمل وصنفت كتابا فى ميزان
الحكمة لخزانته المعمورة فى شهور سنة خمس عشرة وخمسمأة لهجرة بنبينا
محمد المصطفى صلى الله عليه وآله وسلم وتمّ ذلك بسعادته ويمن دولته
العالية الشاملة لجميع الدول بما خصّه الله تعالى به من الشجاعة والبأس
حتى فتح الاقاليم شرقا وغربا ومن الفضايل المجتمعة فيه من طيب العنصر
وكرم الطبع والمنشأ المحمود والمجد السامى وراثة واكتسابا فهو ادام الله
سلطانه سيد اهل العالم ومستوفى جميع مراتب الانسية ونسأل الله تعالى
ن يطيل له فى مدته ويزيد فى علوه وقدرته وسلطانه وبسطته انه ولى
نلك والقادر عليه

الفصل السادس

فى تقسيم الكتاب ۞ وجعلت الكتاب ثلاثة اقسام الاول منها فى الكليات
والمقدمات نحو الثقل والخفة ومراكز الاثقال ومقدار غوص السفن فى الماء
واختلاف اسباب الوزن وصنعة الميزان والقفان وكيفية الوزن به فى
الهواء والمايعات ومقياس المايعات لمعرفة الاخفّ والاثقل منهما من غير
وسائة الصنجات ومعرفة النسب بين الفلزات والجواهر فى الحجم واقوال

I sought assistance from his beams of light irradiating all quarters of the world, and was thereby guided to the extent of my power of accomplishment in this work, and composed a book on the balance of wisdom for his high treasury, during the months of the year 515 of the Hijrah* of our Elect Prophet Muḥammad—may the benedictions of God rest upon him and his family, and may he have peace!

This book is finished by means of his auspiciousness, and the felicity of his high reign, embracing all sovereignties, by virtue of the Supreme God's special gifts to him of fortitude and valor—so that he has subdued the climes of the East and West—and the excellencies united in him, purity of lineage, nobleness of nature, exalted nationality, and lofty grandeur, both by inheritance and conquest. So then, may God perpetuate his reign, who is the chief of the people of the world, the possessor of all the distinctions of humanity! We ask the Supreme God that he would lengthen his days, and increase his eminence, his power, his rule, and his sway—God is equal to that, and able to bring it to pass.

Sect. 6. Division of the Book.

I have divided the book into three parts: 1. General and fundamental topics: such as heaviness and lightness; centres of gravity; the proportion of the submergence of ships in water; diversity of the causes of weight; mechanism of the balance, and the steelyard; mode

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* A. D. 1121-22.

المتقدمين والمتأخرين فى ميزان الماء وما اشاروا اليه وهذا القسم يشتمل
من الكتاب على اربع مقالات مرتبة ‌ والثانى منها فى صنعة ميزان الحكمة
وامتحانه واثبات مراكز الفلزات والجواهر عليه ووضع صنجات لايقة به ثم
العمل به فى تحقق الفلزات وتمييز بعضها من بعض من غير سبك ولا
تخليص بعمل شامل للموازين كلها ومعرفة الجواهر الحجرية وتمييز حقها
من اشباهها وملوناتها وزاد فيه من باب الصرف ودار الضرب بالعمل الكلى
البياعات والمعاملات وهذا القسم يشتمل على ثلاث مقالات ‌ والثالث منها
يشتمل على طرف الموازين وملحها نحو ميزان الدراهم والدنانير من غير
واسطة الصنجات وميزان تسوية الارض على موازاة السطح الافقى وميزان
يعرف بالقسطاس المستقيم يوزن به من حبة الى الف دراهم ودنانير
بثلاث رمانات وميزان الساعات يعرف به الساعات الماضية من ليل او نهار
وكسورها بالدقايق والثوانى وتصحيح الطالع بها بالدرج وكسورها
وهو يشتمل على مقالة واحدة فصار الكتاب ثمانى مقالات وكل مقالة

of weighing with it in air and in liquids; the instrument for measuring liquids, in order to ascertain which is the lighter and which the heavier of two, without resort to counterpoises; knowledge of the relations between different metals and precious stones, in respect to [given] volume; sayings of ancient and modern philosophers with regard to the water-balance, and their intimations on the subject. This part includes four lectures of the book in their order. 2. Mechanism of the balance of wisdom; trial of it; fixing upon it of [the points indicating] the specific gravities of metals and precious stones; adoption of counterpoises suited to it; application of it to the verification of metals and distinguishing of one from another [in a compound], without melting or refining, in a manner applicable to all balances; recognition of precious stones, and distinction of the genuine from their imitations, or similitudes in color. There are here added chapters on exchange and the mint, in connection with the mode of proceeding, in general, as to things saleable and legal tenders. This part embraces three lectures. 3. Novelties and elegant contrivances in the way of balances, such as: the balance for weighing dirhams and dinârs without resort to counterpoises; the balance for levelling the earth to the plane of the horizon; the balance known as "the even balance," which weighs from a grain to a thousand dirhams, or dînârs, by means of three pomegranate-counterpoises; and the hour-balance, which makes known the passing hours, whether of the night or of the day, and their fractions in minutes and seconds, and the exact correspondence therewith of the ascendant star, in degrees and fractions of a degree. This part is in one lecture.

يشتمل على ابواب وكل باب يشتمل على فصول كما يأتي هذا الفهرس ان شاء الله تعالى وهو ولى التوفيق

فهرس كتاب ميزان الحكمة
الذى يسمى الميزان الجامع ثمان مقالات

المقالة الاولى

في المقدمات الهندسية والطبيعية[u] التى يبتنى عليها الميزان الجامع وهي سبعة ابواب

The book is therefore made up of eight lectures. Each lecture includes several chapters, and each chapter has several sections, as will be explained by the following table of contents, if the Supreme God, who is the Lord of Providence, so wills.

Table of Contents of the Book of the Balance of Wisdom, called the Comprehensive Balance, in Eight Lectures.

Lecture First.

Fundamental Principles, Geometrical and Physical, on which the Comprehensive Balance is based. In Seven Chapters.

المقالة الثانية

في بيان الوزن واختلاف اسبابه لثابت وفي مقدمات مراكز الاثقال
وصنعة القفان للمظفر الاسفزاري خمسة ابواب[w]

المقالة الثالثة

في النسب بين الفلزات والجواهر في الحجم لابي الريحان محمد
بن احمد البيروني في خمسة ابواب

Lecture Second.

Explanation of Weight and its Various Causes, according to Thâbit; Fundamental Principles of Centres of Gravity; and Mechanism of the Steelyard, according to 'al-Muzaffar of 'Isfazâr. In Five Chapters.

Lecture Third.

Relations between different Metals and Precious Stones in respect to [Given] Volume, according to 'Abu-r-Raiḥân Muḥammad Bin 'Aḥmad of Birûn. In Five Chapters.

ج في رصد اشياء يحتاج اليها احيانا ب

د في رصد ماء ذراع مكعب وزنة حجم ذراع من الفلزات وزنة ملاء الارض ذهبا ج

ه في دراهم تضاعف ببيوت الشطرنج وحصرها في الاوعية وحرزها في خزانة وذكر العمر الذي ينفق فيه ب

المقالة الرابعة

في ذكر موازين الماء التي ذكرها الحكماء المتقدمون والمتأخرون واشكالها والعمل بها خمسة ابواب

ا في ميزان ارشميدس حكاه مانالاوس والعمل به د

ب في ميزان مانالاوس والطرق التي ميّز بها بين الفلزات المركبة ج

ج في تفسير قول مانالاوس[x] الحكيم في اوزان الفلزات ب

د في ذكر الميزان الطبيعي لمحمد بن زكريا الرازي ج

ه في ميزان الماء على الوجه الذي ذكره الامام عمر الخيامي والعمل به البرهان عليه د

Chap. 3. Observation of Substances occasionally required, in Two Sections.

Chap. 4. Observation of a Cubic Cubit[1] of Water, Weight of a Volume of the Metals one Cubit cube, and Weight of so much Gold as would fill the Earth, in Three Sections.

Chap. 5. Dirhams doubled [successively] for the Squares of the Chess-board, Depositing of them in Chests, their Preservation in a Treasury, and Statement of the Length of Life in which one might expend them, in Two Sections.

LECTURE FOURTH.

Notice of Water-balances mentioned by Ancient and Modern Philosophers, their Shapes, and the Manner of Using them. In Five Chapters.

Chap. 1. Balance of Archimedes, which Menelaus tells of, and Manner of Using it, in Four Sections.

Chap. 2. Balance of Menelaus, and the Ways in which he distinguished between Metals compounded together, in Three Sections.

Chap. 3. Exposition of what Menelaus the Philosopher says respecting the Weights of Metals, in Two Sections.

Chap. 4. Notice of the Physical Balance of Muḥammad Bin Zakarîyâ of Rai, in Three Sections.

المقالة الخامسة

في صنعة ميزان الحكمة وتركيبه وامتحانه وتعريفه اربعة ابواب

ا في صنعة اعضائه كما اشار اليه المظفر بن اسمعيل الاسفزاري د

ب في تركيبها وترتيب تعلق الاعضاء منه د

ج في تعريفه وذكر اسمائه واعضائه مفصلا د

د في امتحانه وتدارك ما وقع ويقع للوزان فيه و

المقالة السادسة

في اتخاذ الصنجات المخصوصة ثم كيفية العمل به والتمييز بين الفلزات المختلطة بالمنقلتين اولا وتمييز كل واحد منهما علما باهون سعي وتعيينهما ثانيا بحساب وزنة اثمان الجواهر

وهي عشرة ابواب

ا في اتخاذ الصنجات المخصوصة به خفة وثقلا ا

ب في تعديل ميزان الحكمة وكيفية وزن الاشياء به وتعداد وجوه الوزن ا

Chap. 5. Water-balance in the Form spoken of by the Eminent Teacher 'Umar 'al-Khaiyâmî, Manner of Using it, and its Basis of Demonstration, in Four Sections.

LECTURE FIFTH.

Mechanism of the Balance of Wisdom, its Adjustment, Trial of it, and its Explanation. In Four Chapters.

Chap. 1. Mechanism of its Constituent Parts, as indicated by 'al-Muẓaffar Bin 'Isma'îl of 'Isfazâr, in Four Sections.

Chap. 2. Adjustment of its Mechanism, and Arrangement of the Connection between its Constituent Parts, in Four Sections.

Chap. 3. Explanation of it, and Express Notice of its Names and the Names of its Constituent Parts, in Four Sections.

Chap. 4. Trial of it, and Statement of what happens or may happen to the Weigher in connection therewith, in Six Sections.

LECTURE SIXTH.

Selection of Appropriate Counterpoises; Mode of Operating thereby, including: 1. *Discrimination between Mixed Metals, by means of the two Movable Bowls, and Distinction of Each One of two Constituents of a Compound, scientifically, with the least labor,* 2. *Arithmetical Determination [as to Quantity] of the Two; and Prices at which Precious Stones have been rated. In Ten Chapters.*

Chap. 1. Selection of Appropriate Counterpoises, as regards Lightness and Heaviness, in One Section.

ج في كيفية اثبات مراكز الفلزات والجواهر عليه بالرصد والجدول ا

د في معرفة تحقيق الفلزات باستعمال المنقلتين والجواهر المفردة
او المفردة والملونة وتمييز المركبة[a2] بعضها من بعض من غير سبك
ولا تخليص باهون سعي واقرب وقت اذا كانت مركبة مثنى
مثنى دون ما ندّ عليه ج

ه في التمييز بينها بالحساب من استعمال المنقلة باوضح سبيل
واسهل حساب والبرهان عليه و

و في نسب الفلزات في وزني الهوائي والمائي والحجم اذا استويا
في الوزن بعضهما[b2] الى بعض بالحساب المحض دون استعمال الميزان ب

ز في غرايب المسايل ب

ح في معرفة وزن الفلزين في الهواء[c2] اذ استوى وزنهما في الماء ب

ط في غرايب المسايل ومعرفة عن الفلز من وزنه وعكسه ج

ى في ذكر قيم الجواهر في الايام الخالية ذكرها ابو الريحان ا

Chap. 2. Levelling of the Balance of Wisdom, Mode of Weighing Things by it, and Application of Numbers to the Conditions of Weight, in One Section.

Chap. 3. Mode of fixing upon the Balance [the points for] the Specific Gravities of Metals and Precious Stones, by Observation and the Table, in One Section.

Chap. 4. Knowledge of the Genuineness of Metals, by use of the two Movable Bowls, as well as of Precious Stones, whether in the State of Nature or partly Natural and partly Colored, and Discrimination of one Constituent from another of a Compound, without melting or refining, with the least labor and in the shortest time, provided they are compounded Two and Two, without any thing adverse, in Three Sections.

Chap. 5. Arithmetical Discrimination between Constituents of Compounds, through Employment of the Movable Bowl, in the plainest way, and by the easiest calculation, and its Basis of Demonstration, in Six Sections.

Chap. 6. Relations between Metals in respect to two Weights: Weight in Air and Weight in Water, and their Mutual Relations in respect to [Given] Volume, when the two [compared] agree in Weight, one with the other, ascertained by Pure Arithmetical Calculation, without Use of the Balance, in Two Sections.

Chap. 7. Certain Singular Theorems, in Two Sections.

" 8. Knowledge of the Weight of two Metals in Air, when they agree in Water-weight, in Two Sections.

Chap. 9. Certain Singular Theorems, and Knowledge of a Metal by its Weight, and the reverse, in Three Sections.

Chap. 10. Statement of the Values of Precious Stones in Past Times, given by 'Abu r Raihân, in One Section.

المقالة السابعة

في ميزان الصرف وتقويمه على كل نسبة مفروضة وزن الدراهم او الدنانير بصنجات اختها ومعرفة الصرف وقيمة كل فلز وجوهر من غير واسطة الصنجات وتركيبه على نسبة السعر والمسعّر والثمن والمثمن وتقويم الاشياء به وفي خمسة[d2] ابواب

ا في ذكر النسب وما يحتاج اليها في المعاملات د

ب في تقويم ميزان الصرف وتعديله ب

ج في اوزان الدراهم او الدنانير بصنجات اختها د

د في الصرف ومعرفة القيم من غير واسطة الصنجات ج

ه في مسايل دار الضرب وغرايب مسايل الصرف د

المقالة الثامنة وفي ثمانية[e2] ابواب

ا في ميزان الدراهم والدنانير من غير واسطة الصنجات د

ب في ميزان الارض وتسوية وجهها على موازاة السطح الافقي ووجوه الحيطان ا

LECTURE SEVENTH.

Exchange-balance; Adjustment of it, for any determined Relation as to the Weight of Dirhams and Dînârs, by Suitable Counterpoises; Knowledge of Exchange, and of the Value of any Metal or Precious Stone, without Resort to Counterpoises; Adjustment of it to the Relation between Impost and the Article charged therewith, as also to that between Price and the Article appraised; and Settlement of Things by means of it. In Five Chapters.

Chap. 1. Statement concerning Relations, and their Necessity in the Case of Legal Tenders, in Four Sections.

Chap. 2. Adjustment of the Exchange-balance, and Levelling of it, in Two Sections.

Chap. 3. Weights of Dirhams and Dînârs, estimated by Suitable Counterpoises, in Four Sections.

Chap. 4. Exchange, and Knowledge of Values without Resort to Counterpoises, in Three Sections.

Chap. 5. Theorems pertaining to the Mint, and Singular Theorems relative to Exchange, in Four Sections.

LECTURE EIGHTH. *In Eight Chapters.*

Chap. 1. Balance for weighing Dirhams and Dînârs, without Resort to Counterpoises, in Four Sections.

ج فى القسطاس المستقيم والوزن به من حبّة الى الف درهما
ودينارا بثلث رمانات د

د فى ميزان الساعات فى صنعة عموده وما عليه من الحساب ب

ه فى صنعة خزانة الماء او الرمل وما يتصل بها ز

و فى الرقوم والرمانات الثلث ه

ز فى معرفة الساعات وكسورها ا

ح فى صنعة الميزان اللطيف والعمل به للازمان وكسورها ا

الجمل

المقالات	الابواب	الفصول
ثمانى	تسعة واربعون[f2]	ماية واحد وسبعون[g2]

Chap. 2. Earth-balance, Levelling of the Earth's Surface parallel with the Plane of the Horizon, and Reduction of the Surfaces of Walls to a Vertical Plane, in One Section.

Chap. 3. Even Balance, and Weighing with it from a Grain to a Thousand Dirhams or Dînârs, by means of three Pomegranate-counterpoises,[2] in Four Sections.

Chap. 4. Hour-balance, Mechanism of its Beam, and Arithmetical Calculation [put] upon it, in Two Sections.

Chap. 5. Mechanism of the Reservoir of Water or Sand, and Matters therewith connected, in Seven Sections.

Chap. 6. Numerical Marks and three Pomegranate-counterpoises, in Five Sections.

Chap. 7. Knowledge of Hours and their Fractions, in One Section.

" 8. Mechanism of the Delicate Balance, and Employment of it for Times and their Fractions, in One Section.

In all, Eight Lectures, Forty-nine Chapters and One Hundred and Seventy-one Sections.*

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* Although our author has taken pains to define by synchronisms the periods of most of the philosophers whom he refers to in his introduction and table of contents, I think it proper to add, here, some more exact intimations of the dates which concern them.

The Hiero mentioned must be Hiero ii., who died B. C. 216, at the age of not less than ninety years; and our author is evidently wrong in placing Archimedes before the time of Alexander the Great. It is well known that the great Greek geometrician was killed at the taking of Syracuse by Marcellus, B. C. 212. Euclid composed his Elements about fifty years after the death of Plato, B. C. 347. Menelaus was a celebrated mathematician of the time of Trajan, A. D. 98–117. But I have not been able to find any notice to guide me in identifying Dûmâṭiyâ̂nûs. Pappus was probably cotemporary with Theodosius the Great, A. D. 379–395. The philosophers of the time of Mâmûn must have lived between A. D. 813 and 833. The great geometrician Thâbit Bin Ḳurrah was born in the reign of Mutassim, A. H. 221 (A. D. 835), at Ḥarrân, and died at Baghdâd A. H. 288 (A. D. 900). See 'Ibn-Khal-

Before going farther I must endeavor to discover who our author may have been, thus supplying a deficiency occasioned by his too great modesty.[3]

. . . .

Our author continues as follows:

ونشرع فى القسم الاول من الكتاب متوكلين على الله ومصلين على نبيه محمد وآله وهذا القسم يشتمل على اربع مقالات نذكرها مفصلة مشروحة ان شاء الله تعالى

المقالة الاولى

فى المقدمات الطبيعية والرياضية

نقول وبالله التوفيق ان الاحاطة برؤس مسايل مراكز الاثقال والثقل والخفة وكيفية اختلافهما فى الرطوبة والهواء والرسوب والطفو اعنى العلم الآلى فى

We now enter upon the First Part of the book, relying upon God, and imploring benedictions upon His Prophet Muhammad and his family. This Part includes four Lectures, which we shall set forth distinctly and clearly, if the Supreme God so wills.

Lecture First.

Fundamental Principles, Physical and Mathematical.

We say—God ordering all things by His Providence—that the comprehension of the main theorems relative to centres of gravity, and

likân's Wafayât, ed. De Slane, p. 147. As to Muḥammad Bin Zakarîyâ of Rai, he is said to have died A. H. 320 (A. D. 932), at a great age. [See Wüstenfeld's Gesch. d. Arab. Aerzte u. Naturforscher, p. 41.] Consequently, he was cotemporary with Naṣr Bin Aḥmad the Sâmânide. According to Haji Khalfah, 'Ibn 'al-'Amîd died A. H. 360 (A. D. 970), so that he was cotemporary with the Dailamite Rukn 'ad-Daulah. The same authority gives us the date A. H. 428 (A. D. 1036) for the death of 'Ibn-Sînâ. See Haji Khalfae Lex., ed. Flügel, iv. 496. The Ḥabîb 'as-Siyar of Khondemîr places it in the Ramadhân of A. H. 427, at Ḥamadân, where I saw his tomb, in ruins, in 1852. 'Abu-r-Raihân Muḥammad, "surnamed 'al-Birûnî, because originally of the city called Birûn, in the valley of the Indus, passed his youth, and perhaps was born, in Kharizm. He was one of the society of savans formed in the capital of Kharizm, at the court of the prince of the country, and of which the celebrated Avicenna ['Ibn-Sînâ] was a member. Avicenna, so long as he lived, kept up relations of friendship with him. When Maḥmûd undertook his expeditions into India, 'al-Birûnî attached himself to his fortunes, and passed many years of his life in India, occupied in making himself master of the Indian sciences; he also endeavored to instruct the Hindus in Arab science, by composing certain treatises which were translated into Sanskrit." See Reinaud's learned paper in Journ. Asiat. for Aug. 1844, 4me Série, iv. 123. Maḥmûd of Ghaznah, as is well known, made his first expedition into India A. D. 1000. 'Abû-Ḥafṣ 'Umar 'al-Khaiyâmî, author of an algebraic treatise lately translated by Woepcke, was born, according to a learned notice by this savant in Journ. Asiat. for Oct.-Nov. 1854, 5me Série, iv. 348, at Nîsâpûr, and died in that same city A. D. 1123.

Being limited to the resources of my own library, I am unable to assign more definite dates to the other philosophers mentioned in this treatise.

الثقل والخفة وغوص الاجسام الثقال فى الماء على سبيل الاخبار المأخوذ بالتقليد نافعة جدا فى علم ميزان الحكمة وتسهل تصوره لمعانيه حتى اذا اعاد على تلك المسايل متعرفا وجوه براهينها اتاها بفكرة مجردة لا يجتمع عليها تعب كلى الجانبين والقول فيها يشتمل على سبعة ابواب

الباب الاول منها

فى روس مسايل من مراكز الاثقال عن ابى سهل الكوهى[h2] وابن الهيثم البصرى[i2] وهو معين الناظر فيه على تصور معانيه على تسعة فصول

الفصل الاول

الاول[j2] الثقل هو القوة التى بها يتحرك الجسم الثقيل الى مركز العالم والثانى الجسم الثقيل هو الذى يتحرك بقوة ذاتية ابدا الى مركز العالم فقط اعنى ان الثقيل هو الذى له قوة تحركه الى نقطة المركز وفى الجهة ابدا التى فيها المركز ولا تحركه تلك القوة فى جهة غير تلك الجهة وتلك القوة

heaviness and lightness, and the mode of difference in respect thereto, in a liquid and in air, and relative to submergence and floating—I mean, the comprehension of what is known, in general, respecting heaviness and lightness, and the sinking of heavy bodies in water, considered in the light of traditions accepted on authority, is of very great utility with reference to the science of the balance of wisdom, and facilitates the conception of its ideas. After that, on reverting to those theorems, as an investigator of the grounds of demonstration on which they rest, one lays hold of them by a simple act of thought, without any toiling in all directions at once. What is to be said on these main theorems occupies seven chapters.

Chapter First.

Main Theorems relative to Centres of Gravity, according to 'Abû-Sahl of Kûhistân and 'Ibn 'al-Haitham of Basrah—to aid the Speculator in the Science of the Balance of Wisdom to the Conception of its Ideas. In Nine Sections.

Section First.

1. Heaviness is the force with which a heavy body is moved towards the centre of the world. 2. A heavy body is one which is moved by an inherent force, constantly, towards the centre of the world. Suffice it to say, I mean that a heavy body is one which has a force moving it towards the central point, and constantly in the direction of the centre, without being moved by that force in any different direction; and that the force referred to is inherent in the body, not derived from without, nor separated from it—the body not resting at any point out of the centre, and

هي لذاته لا مكتسبة من خارج وغير مفارقة له مادام على غير المركز ومتحركا بها ابدا ما لم يعقه عايق الى ان يصير الى مركز العالم

الفصل الثانى

الاول والاجسام الثقال مختلفة القوى فنها ما قوته اعظم وهي الاجسام الكثيفة والثانى ومنها ما قوته اصغر وهي الاجسام السخيفة والثالث وكلما كان اشد كثافة كان اعظم قوة . والرابع وكلما كان اشد سخافة كان اصغر قوة والخامس والاجسام المتساوية القوى هى المتساوية الكثافة والسخافة التى المقادير المتساوية منها المتشابهة الاشكال متساوية الثقل ولنسم هذه الاجسام المتساوية فى القوة والسادس والاجسام المختلفة القوى هي التى ليست كذلك ولنسمها المختلفة القوى

الفصل الثالث

الاول واذا تحرك جسم ثقيل فى اجسام رطبة فان حركته فيها بحسب رطوباتها فتكون حركته فى الجسم الارطب اسرع الثانى واذا تحرك فى جسم رطب جسمان متساويا الحجم متشابها الشكل مختلفا الكثافة فان حركة الجسم الاكثف فيه تكون اسرع الثالث واذا تحرك جسمان متساويا الحجم متساويان فى القوة مختلفا الشكل فان الذى يلقى الجسم

being constantly moved by that force, so long as it is not impeded, until it reaches the centre of the world.

Section Second.

1. Of heavy bodies differing in force some have a greater force, which are dense bodies. 2. Some of them have a less force, which are rare bodies. 3. Any body whatever, exceeding in density, has more force. 4. Any body whatever, exceeding in rarity, has less force. 5. Bodies alike in force are those, of like density or rarity, of which the corresponding dimensions are similar, their shapes being alike as to gravity. Such we call bodies of like force. 6. Bodies differing in force are those which are not such. These we call bodies differing in force.

Section Third.

1. When a heavy body moves in liquids, its motion therein is proportioned to their degrees of liquidness; so that its motion is most rapid in that which is most liquid. 2. When two bodies alike in volume, similar in shape, but differing in density, move in a liquid, the motion therein of the denser body is the more rapid. 3. When two bodies alike in volume, and alike in force, but differing in shape, move in a liquid, that which has a smaller superficies touched by the liquid moves therein more

الرطب منه سطح اصغر تكون حركته فيه اسرع . الرابع واذا تحرك فى جسم رطب جسمان متساويان فى القوة مختالفا الحجم فان حركة الاعظم فيه ابطاء

الفصل الرابع

الاول والاجسام الثقال قد يتساوى اثقالها وان كانت مختلفة فى القوة مختلفة فى الشكل الثانى والاجسام المتساوية الثقل هى التى اذا تحركت فى جسم واحد من الاجسام الرطبة من نقطة واحدة كانت حركاتها متساوية اعنى انها تجوز فى ازمنة متساوية مسافات متساوية الثالث والاجسام المختلفة الثقل هى التى اذا تحركت على هذه الصفة كانت حركاتها مختلفة واعظمها ثقلا اسرعها حركة الرابع والاجسام المتساوية فى القوة والحجم والشكل والبعد عن مركز العالم متساوية الخامس وكل جسم ثقيل يكون على مركز العالم فان مركز العالم يكون فى وسطه ويكون ميل اجزائه مع جميع جهاته الى مركز العالم ميلا متساويا ويكون كل السطوح التى تخرج من مركز العالم تقسم كل واحد منها الجسم بقسمين معادلى الثقل عند ذلك السطح السادس وكل السطوح الذى يفصله ولا يمرّ بمركز العالم يقسمه بقسمين غير معادلى الثقل عند ذلك السطح

rapidly. 4. When two bodies alike in force, but differing in volume, move in a liquid, the motion therein of the larger is the slower.*

Section Fourth.

1. Heavy bodies may be alike in gravity, although differing in force, and differing in shape. 2. Bodies alike in gravity are those which, when they move in a liquid from some single point, move alike—I mean, pass over equal spaces in equal times. 3. Bodies differing in gravity are those which, when they move as just described, move differently; and that which has the most gravity is the most rapid in motion. 4. Bodies alike in force, volume, shape, and distance from the centre of the world, are like bodies. 5. Any heavy body at the centre of the world has the world's centre in the middle of it; and all parts of the body incline, with all its sides, equally, towards the centre of the world; and every plane projected from the centre of the world divides the body into two parts which balance each other in gravity, with reference to that plane. 6. Every plane which cuts the body, without passing through the centre of the world, divides it into two parts which do not balance each other

* The MS. reads أسرع, but it is evident that our author would say .

السابع وكل جسم ثقيل فان النقطة التى منه ينطبق على مركز العالم
اذا كان ساكنا عليه يسمى مركز الثقل لذلك الجسم

الفصل الخامس

الاول والجسمان المتعادلا الثقل عند نقطة مفروضة هما اللذان يمكن اذا
اضمّا الى جسم ثقيل تكون تلك النقطة مركز ثقله وصار مركزا ثقلهما عن
جنبتى تلك النقطة على خط مستقيم ينتمّ بتلك النقطة ان لا يتغير وضع
ذلك الجسم وتصير تلك النقطة مركز ثقل مجموعهما الثانى والجسمان
المتعادلان من الثقل عند سطح مفروض هما اللذان يمكن اذ اضمّا الى
جسم ثقيل يكون مركز ثقله على ذلك السطح ان لا يتغير وضع ذلك
الجسم ويكون مركز ثقل الجميع على ذلك السطح الثالث والاثقال
المتعادلة لثقل واحد يعينه على مركز واحد فهى متساوية الرابع واذا
اضمّ الى اثقال متعادلة عند ذلك المركز ولم يتغير مركز ثقلهما فان الجميع
متعادلة عند ذلك المركز الخامس واذ اضمّ الى اثقال متعادلة عند سطح
مفروض اثقال متعادلة عند ذلك السطح فان الجميع متعادلة عند ذلك

with reference to that plane. 7. That point in any heavy body which coincides with the centre of the world, when the body is at rest at that centre, is called the centre of gravity of that body.

Section Fifth.

1. Two bodies balancing each other in gravity, with reference to a determined point, are such that, when they are joined together by any heavy body of which that point is the centre of gravity, their two [separate] centres of gravity are on the two sides of that point, on a right line terminating in that point—provided the position of that body [by which they are joined] is not varied; and that point becomes the centre of gravity of the aggregate of the bodies. 2. Two bodies balancing each other in gravity, with reference to a determined plane, are such that, when they are joined together by any heavy body, their common centre of gravity is on that plane—provided the position of that body [by which they are joined] is not varied; and the centre of gravity common to all three bodies is on that plane. 3. Gravities balancing each other relatively to any one gravity, which secures a common centre to the aggregate, are alike. 4. When addition is made to gravities balancing each other relatively to that centre, and the common centre of the two is not varied, all three gravities are in equilibrium with reference to that centre. 5. When addition is made to gravities balancing each other, with reference to a determined plane, of gravities which are themselves in equilibrium with reference to that plane, all the gravities balance with

السطح السادس واذا نقص من اثقال متعادلة اثقال متعادلة فلم يتغير
مركز ثقل الجميع فان الباقية متعادلة السابع وكل جسم ثقيل يعادل جسما
ثقيلا فانه لا يعادل بجميع ثقله ولا باكثر من ثقله جزء من ذلك الجسم ما
لم يتغير وضع احدهما الثامن والاجسام المتساوية فى القوة المتساوية
فى العظم المتشابهة الاشكال التى ابعاد مراكز اثقالها من نقطة واحدة
وية هى متعادلة الثقل بالاضافة الى تلك النقطة ومتعادلة[k2] الثقل بالاضافة
الى . السطح المستوى
عنده وضعا متشابها التاسع وكل جسمين ثقيلين فمجموع ثقلهما
ثقل كل واحد منهما العاشر والاجسام الثقال المتساوية البعد عن مركز
العالم هى التى تكون الخطوط التى تخرج من مركز العالم الى مراكز[12] اثقالها
متساوية

الفصل السادس

الاول كل جسم ثقيل يتحرك الى مركز العالم فانه لا يتجاوز المركز وانه اذا
انتهى اليه انتهت حركته الثانى واذا انتهت حركته صار ميل جميع
اجزائه الى المركز ميلا متساويا الثالث واذا انتهت حركته فان وضع

reference to that plane. 6. When subtraction is made from gravities balancing each other, of gravities which are themselves in equilibrium, and so the centre of gravity of the aggregate is not varied, the remaining gravities balance each other. 7. Any heavy body in equilibrium with any heavy body does not balance a part of the latter with the whole of its own gravity, nor with more than its own gravity, so long as the position of neither of the two is varied. 8. Bodies alike in force, alike in bulk, similar in shape, whose centres of gravity are equally distant from a single point, balance each other in gravity with reference to that point; and balance each other in gravity with reference to an even plane passing through that point; and such bodies are alike in position with reference to that plane. 9. The sum of the gravities of any two heavy bodies is greater than the gravity of each one of them. 10. Heavy bodies alike in distance from the centre of the world are such that lines drawn out from the centre of the world to their centres of gravity are equal.

Section Sixth.

1. A heavy body moving towards the centre of the world does not deviate from the centre; and when it reaches that point its motion ceases.* 2. When its motion ceases, all its parts incline equally towards

* This proves that the theory of momenta was entirely unknown to the Arabs of the twelfth century, excepting for the case of the lever.

المركز منه لا ينتغير   الرابع   واذا تحرك الى المركز اجسام ثقال ولم يعقها
عايق فانها يلتقى عند المركز ويصير وضع المركز منها وضعا لا يتغير
الخامس   وكل جسم ثقيل فله مركز ثقل   السادس   وكل جسم ثقيل فان
كل سطح مستو يخرج من مركز ثقله فانه يقسمه بقسمين متعادلى الثقل
السابع   واذا قسمه بقسمين متعادلى الثقل فان مركز ثقله على ذلك السطح
الثامن   وان مركز ثقله هو نقطة واحدة

الفصل السابع

الاول   كل جسمين ثقيلين بينهما واصل بحفظ وضع احدهما عند الاخر
فلمجموعهما مركز ثقل وهو نقطة واحدة فقط   الثانى   كل جسمين ثقيلين
يصل بينهما جسم ثقيل يكون مركز ثقله على الخط المستقيم الذى يصل
مبين مركزى ثقلهما فان مركز ثقل الجميع على ذلك الخط   الثالث   كل
جسم ثقيل يعادل جسما ثقيلا فان كل جسم مساو له فى الثقل فانه يعادل
ذلك الثقل اذا لم ينتغير المراكز   الرابع   كل جسمين متعادلين يرفع احدهما
ويوضع على مركز ثقله جسم اثقل منه فانه لا يعادل الجسم الثانى ولا يعادل
الا جسما اثقل منه

the centre. 3. When its motion ceases, the position of its centre of gravity is not varied. 4. When several heavy bodies move towards the centre, and nothing interferes with them, they meet at the centre; and the position of their common centre of gravity is not varied. 5. Every heavy body has its centre of gravity. 6. Any heavy body is divided by any even plane projected from its centre of gravity into two parts balancing each other in gravity. 7. When such a plane divides a body into two parts balancing each other in gravity, the centre of gravity of the body is on that plane. 8. Its centre of gravity is a single point.

Section Seventh.

1. The aggregate of any two heavy bodies, joined together with care as to the placing of one with reference to the other, has a centre of gravity which is a single point. 2. A heavy body which joins together any two heavy bodies has its centre of gravity on the right line connecting their two centres of gravity; so that the centre of gravity of all three bodies is on that line. 3.* Any heavy body which balances a heavy body is balanced by the gravity of any other body like to either in gravity, when there is no change of the centres of gravity. 4. One of any two bodies which balance each other being taken away, and a heavier body being placed at its centre of gravity, the latter does not balance the second r; it balances only a body of more gravity than that has.

الفصل الثامن

الاول كل جسم متساوى السطوح متشابه الاجزاء فان مركز ثقله هو
مركزه اعنى النقطة التى يتقاطع عليها اقطاره الثانى كل جسمين متوازى
السطوح متساويين فى القوة وارتفاعهما متساويان وارتفاعهما على قواعدهما
على زوايا قايمة فان نسبة ثقل احدهما الى ثقل الاخر كنسبة عظم احدهما
الى عظم الاخر الثالث كل جسم متوازى السطوح يفصله سطح على
موازاة سطحين متقابلين من سطوحه فيقسمه بجسمين متوازى السطوح
ويستخرج مركزا[m2] الجسمين ويوصل بينهما نخطّ مستقيم ويستخرج مركز
جميع الجسم وهو ايضا على هذا الخط فان نسبة ثقلى الجسمين احدهما
الى الاخر كنسبة قسمى الخط احدهما الى الاخر بالتكافى الرابع
كل جسمين ثقيلين متصّلين فان نسبة ثقل احدهما الى ثقل الاخر كنسبة
قسمى الخط الذى عليه مراكز اثقالها الثلاث الذى لكل واحد منهما
ولمجموعهما احدهما الى الاخر بالتكافى

Section Eighth.

1. The centre of gravity of any body having like planes and similar parts is the centre of the body — I mean, the point at which its diameters intersect. 2. Of any two bodies of parallel planes, alike in force, and alike in altitude — their common altitude being at right angles with their bases — the relation of the gravity of one to the gravity of the other is as the relation of the bulk of one to the bulk of the other. 3. Any body of parallel planes, which is cut by a plane parallel with two of its opposite planes, is thereby divided into two bodies of parallel planes; and the two have [separate] centres of gravity, which are connected by a right line between them; and the body as a whole has a centre of gravity, which is also on this line. So that the relation of the gravities of the two bodies, one to the other, is as the relation of the two portions of the line [connecting their separate centres of gravity and divided at the common centre], one to the other, inversely. 4. Of any two bodies joined together, the relation of the gravity of one to the gravity of the other is as the relation of the two portions of the line on which are the three centres of gravity — namely, those pertaining to the two taken separately, and that pertaining to the aggregate of the two bodies — one to the other, inversely.

Section Ninth.

1. Of any two bodies balancing each other in gravity, with reference to a determined point, the relation of the gravity of one to the gravity of the other is as the relation of the two portions of the line which passes

الفصل التاسع

الاول كل جسمين متعادلى الثقل عند نقطة مفروضة فان نسبة ثقل
احدهما الى ثقل الاخر كنسبة قسمى الخط الذى يمر بتلك النقطة ويمر
بمركزى ثقليهما احدهما الى الاخر الثانى كل جسمين ثقيلين يعادلان
جسما واحدا ثقيلا بالقياس الى نقطة واحدة فان اقربهما من تلك النقطة
اثقل من ابعدهما الثالث كل جسم ثقيل يعادل جسما ثقيلا بالقياس
الى نقطة ثم ينتقل الجسم فى ضد الجهة التى فيها الجسم الاخر ويصير
ايضا مركز ثقله على الخط المستقيم الذى عليه المركز فانه كلما بعد كان
ثقله اعظم الرابع كل جسمين ثقيلين متساوين فى الحجم والقوة
والشكل مختلفى البعد عن مركز العالم فان اكثرهما بعد اعظمهما[n2] ثقلا
تمت مسايل مراكز الاثقال

through that point, and also passes through their two centres of gravity, one to the other. 2. Of any two heavy bodies balancing a single heavy body relatively to a single point, the one nearer to that point has more gravity than that which is farther from it. 3. Any heavy body balancing another heavy body relatively to a certain point, and afterwards moved in the direction towards that other body, while its centre of gravity is still on the same right line with the [common] centre, has more gravity the farther it is from that point. 4. Of any two heavy bodies alike in volume, force, and shape, but differing in distance from the centre of the world, that which is farther off has more gravity.

End of the theorems relative to centres of gravity.

The second chapter is entitled Theorems of Archimedes with respect to Weight and Lightness. I shall not give a translation of it, since it contains nothing which is not known. Our author commences by quoting from the Greek geometrician, though without specifying the work from which he derives the quotation, to the effect that different bodies, solid and liquid, are distinguished by their respective weights; then he proceeds to enunciate, without demonstration, the principle of Archimedes, that the form of a liquid in equilibrium is spherical; that a floating body will sink into the water until it shall have displaced a volume of water equal in weight to its own entire weight; and finally, that if a body lighter than a liquid be plunged into that liquid, it will rise from it with a force proportionate to the difference between the weight of the submerged body and that of an equal volume of the liquid.

The title of the third chapter is Theorems of Euclid respecting Weight and Lightness, and respecting the Measuring of Bodies by one another. It contains sundry geometrical definitions respecting volumes, the enunciation of the well-known equation of dynamics expressing the relation between the velocity of motion, the space traversed, and the time, $v=\frac{s}{t}$, and that of the principle that gravity acts upon a body in the direct ratio of its mass.

The fourth chapter has for its title Theorems of Menelaus respecting Weight and Lightness. It contains only a few well-known developments of the principles of Archimedes applied to solid and hollow bodies (جرم مصمّت and جرم مجوّف), and I shall do no more than cite from it some of the technical terms made use of. The water into which a solid is plunged is called الماء المثل, "like water," if the water displaced by the immersed body be of the same weight with that body; and the latter is designated الجرم المثل, "like body." If of less weight, the body is called الجرم الراسب, "sinking body;" if of greater weight, it is styled الجرم الطافى, "floating body."

The fifth chapter contains a recapitulation of the principles of centres of gravity, and is here given entire, with a translation:

الباب الخامس

فى مسايل معادة للبيان وهو يشتمل على ثلثة فصول

الفصل الاول

فى اختلاف اوزان الاجسام الثقال فى بعد واحد من مركز العالم

اقول ان الاجرام الاسطقسية لا تخلو عن معاوقة بعضها لبعض نحو جهتى المركز والمحيط بخلاف الاجرام الفلكية اذا حول الى جوّ اكثف او خلافه

الثانى اذا حول الجسم الواحد الثقيل من جوهر ما من الجو الالطف الى الجو الاكثف يصير اخفّ وزنا من الاكثف الى الالطف يصير اثقل وهذا

CHAPTER FIFTH.

Theorems recapitulated for the sake of Explanation. In Three Sections.

SECTION FIRST.

Difference in the Weights of Heavy Bodies, at the same Distance from the Centre of the World.

1. I say that elementary bodies — differing in this from the celestial spheres — are not without interference, one with another [as to motion], in the two directions of the centre and of the circumference of the world, [as appears] when they are transferred from a denser to a rarer air, or the reverse. 2. When a heavy body, of whatever substance, is

حكم كلى بجميع الاجسام الثقال   الثالث   اذا فرض جسمان ثقيلان فان
كانا من جوهر واحد فاعظمهما جسما اكثرهما وزنا   الرابع   واذا كانا من
جوهرين مختلفين واتفقا فى الوزن ثم حولا الى الجوّ الاكثف فيصيران
اخفّ الا ان المكسّر منهما وهو الذى هو اصغرهما جسما اثقلهما وزنا والاخر
اخفّهما   الخامس   وان حولا الى الجو الالطف فيصيران اثقل الا ان المكسر
منهما وهو الذى هو اصغرهما جسما اخفّهما وزنا والاخر اثقلهما

الفصل الثانى

الاول   الجسم الثقيل اذا تحرك فى مايع يعاوق بعضهما بعضا ولهذا يعاوق
الماء جرم الشئ الثقيل الذى القى فيه ويوهن قوته وثقله بقدر جرمه
حتى يخفّ الثقل فى الماء بقدر وزن الماء المساوى لجرمه فينقص عن ثقله
بقدره وكلما كان الجرم المتحرك اعظم كانت المعاوقة اكثر وتسمى هذه
المعاوقة فى ميزان الحكمة الشول   الثانى   واذا وزن جرم فى الهواء ثم وزن
فى كفة الماء فان عموده يشول بقدر وزن الماء الذى يساوى جرم الموزون

transferred from a rarer to a denser air, it becomes lighter in weight; from a denser to a rarer air, it becomes heavier. This is the case universally, with all heavy bodies. 3. When one fixes upon two heavy bodies, if they are of one and the same substance, the larger of the two in bulk is the weightier of them. 4. When they are of two different substances, and agree in weight, and are afterwards transferred to a denser air, both become lighter; only that the deficient one, that is, the smaller of the two in bulk, is the weightier of them, and the other is the lighter. 5. If the two are transferred to a rarer air, both become heavier; only that the deficient one, that is, the smaller of the two in bulk, is the lighter of them in weight, and the other is the heavier.

Section Second.

1. When a heavy body moves in a liquid, one interferes with the other; and therefore water interferes with the body of any thing heavy which is plunged into it, and impairs its force and its gravity, in proportion to its body. So that gravity is lightened in water, in proportion to the weight of the water which is equal [in volume] to the body having that gravity; and the gravity of the body is so much diminished. As often as the body moving [in the water] is increased in bulk, the interference becomes greater. This interference, in the case of the balance of wisdom, is called the rising up [of the beam]. 2. When a body is weighed in air, and afterwards in the water-bowl, the beam of the balance rises, in proportion to the weight of the water which is equal in volume to the body weighed; and therefore, when the counterpoises are proportionally lessened, the beam is brought to an equilibrium, parallel

ولهذا اذا نقص من الصنجات بقدره يعتدل العمود على موازاة سطح الافق
الثالث ويختلف قوة حركة الاجرام فى الهواء والماء بسبب اختلاف اشكالها
ايضا الرابع واذا استقرّ جرم فى الكفة اى يشول بحسب مقدار جرمه
لا بحسب شكله الخامس يسفو بقدر قوته لا بقدر جرمه p^2 السادس
الاجرام الثقال يعاوقها الهواء وهى بذواتها فى الحقيقة اثقل من ثقلها الموجود
فى ذلك السابع واذا نقلت الى هواء الطف كانت اثقل وعلى خلافه اذا
نقلت الى هواء اكثف كانت اخف

الفصل الثالث

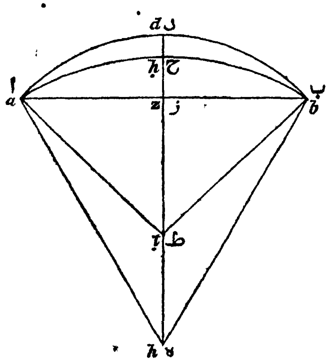
الاول كل جرم ثقيل معلوم الوزن لبعد مخصوص من مركز العالم فانه
يختلف زنته بحسب اختلاف بعده منه فانه كلما كان ابعد كان اثقل واذا
قرب كان اخف ولهذا تكون نسبة الثقل الى الثقل كنسبة البعد الى
البعد منه الثانى ان ميل كل ثقل الى مركز العالم ومسقط حجره من
سطح الارض هو مقامه وهما على السهم الذى يخرج من مركز العالم ويمر
على المقام المذكور الثالث كل شخصين متساويين قايمين على دايرة
عظيمة من دواير سطح الارض تكون المسافة بين رأسيهما اكثر مما بين

with the plane of the horizon. 3. The cause of the differing force of the motion of bodies, in air and in water, is their difference of shape. 4. Yet, when a body lies at rest in the water-bowl, the beam rises according to the measure of the volume of the body, not according to its shape. 5. The rapidity of the motion of the beam is in proportion to the force of the body, not to its volume. 6. The air interferes with heavy bodies; and they are essentially and really heavier than they are found to be in that medium. 7. When moved to a rarer air, they are heavier; and, on the contrary, when moved to a denser air, they are lighter.

Section Third.

1. The weight of any heavy body, of known weight at a particular distance from the centre of the world, varies according to the variation of its distance therefrom; so that, as often as it is removed from the centre, it becomes heavier, and when brought nearer to it, is lighter. On this account, the relation of gravity to gravity is as the relation of distance to distance from the centre. 2. Any gravity inclines towards the centre of the world; and the place where the stone having that gravity falls, upon the surface of the earth, is its station; and the stone, together with its station, is on a straight line drawn from the centre of the world to the station mentioned. 3. Of any two like figures, standing on one of the great circles of the surface of the earth, the distance

قاعدتيهما لانهما على سهمين خارجين من مركز العالم ويصيران ساقى مثلث
رأسهما مركز العالم وقاعدته رأساهما واذا وصل مقاما[q2] الشخصين صار شكل
مثلثين متشابهين فاطولهما ساقا اعظمهما[r2] قاعدة الرابع كل سطح مستو
موازٍ للافق فان موقع العمود عليه من مركز العالم هو وسطه واقرب اجزائه
الى مركز العالم مثل سطح اب ومركز العالم ه والعمود على اب منه هو هز



وهو اقصر خط يقع بينهما الخامس كل
مايع صبّ على سطح اب فيجتمع عند ح
داخل سطح احب الكرى من مركز ه فاذا
زاد حجمه عليه انصبّ من جوانب اب
وانما كان ذلك كذلك لان كل ثقيل مايعا كان
او غيره يقصد من الصعود الى الهبوط ويقف
على السوا من مركز العالم ولهذا لا يكون
وجه الماء مسطحا بل يكون محدبا كرى
الشكل ولهذه العلة من كان فى البحر وكان فى البعد منه منارة فاول ما يظهر

between the apexes is greater than that between the bases, because the two are on two straight lines drawn from the centre of the world, making the two legs of a triangle, of which the apex is the centre of the world, and the base [includes] the two apexes. When the stations of the two figures are connected [by a right line], we get the shape of two similar triangles, the longer of which as to legs is the broader as to base. 4. The place of incidence of a perpendicular line from the centre of the world, falling upon any even plane parallel with the horizon, is the middle of that plane, and the part of it which is nearest to the centre of the world. Thus,[4] let the plane be *a b*, the centre *h*, and the perpendicular line upon *a b* from the centre *h z*—that is the shortest line between the centre and the plane. 5. Let any liquid be poured upon the plane *a b*, and let its gathering-point be *ḥ*, within the spherical surface *a ḥ b*, [formed by attraction] from the centre *h*, then, in case the volume of the liquid exceeds that limit, it overflows at the sides of *a b*. This is so only because any heavy body, liquid or not, inclines from above downwards, and stops on reaching the centre of the world; for which reason the surface of water is not flat, but, on the contrary, convex, of a spherical shape. On this account, one who is on the sea, with a lighthouse in the distance, first descries its summit, and afterwards makes out to discover, little by little, what is below the summit, all of which was before, as a matter of course, concealed; for, excepting the convexity of the earth, there is nothing to hide every other part but the summit, in the case supposed. 6. Let any sphere be formed by gravita-

منها رأسها ثم جعل يظهر ما تحته قليلا قليلا كان مستورا لا محالة دون
رأسه فلا ساتر اذا دونه غير حدبة الارض السادس وكل كرة دحرجت
على سطح اب فتدحرج وتتقدم وتتأخر ثم تقف على نقطة د
بخلاف من ظنّ انها تتحير وتتحرك دايما السابع من المايعات فى الاوانى
تسع اكثر حجما اذا كانت اقلّ بعدا من مركز العالم وتسع اقلّ حجما اذا
كانت فى بعد اكثر مثاله اناء[s2] ابح على بعد ه الابعد والسطح الكرى للماء[t2]
على رأس الاناء[u2] من مركز العالم احب يوسع[v2] فيه من المايع ما فى تجويف
الاناء[w2] وقطعة من سطح الكرة هى ما تجدها سطحا احب ازب وسهمهما زح
واما اناء[x2] كانت[y2] على بعد طز الاقرب اذا فرضنا مركز العالم نقطة ط وقطعة
سطح الكرة الحادثة على رأس الاناء[z2] ادب وسهمهما زد فيزيد ما فى الاناء
بفضله ما بين سطحى كريين مختلفى البعد عن مركز العالم وذلك ما
اردنا ان نذكر

tion over the plane *ab*—after being so formed, and oscillating to and fro, it stops at a point *d*, contrary to the opinion of those who think that it is accumulated and oscillates perpetually. 7. Of liquids in receptacles, they contain a greater volume when nearer to the centre of the world, and when farther from it contain a less volume. Thus, let *abḥ* be [the bulge of water in] a receptacle, at the greater distance from *h* [the centre], and within the spherical surface of the water, *aḥb*, over the top of the receptacle [by attraction] from the centre of the world, let the liquid in the hollow of the receptacle be contained, and let a section of the surface of the sphere—which you perceive to be not a plane—be *aḥb* by *azb*, and let the right line between these two be *zḥ*; and, on the other hand, let there be a receptacle at the less distance *ṭz*, in case we fix upon *ṭ* as the centre of the world, and let the new section of the surface of the sphere be *adb*, over the top of the receptacle, [by *azb*], and let the right line between these two be *zd*. So then, what is in the receptacle increases by the excess of *zd* [over *zḥ*], namely, the interval between two spherical surfaces at different distances from the centre of the world—which is what we wished to state.

I shall not stop to point out certain inaccuracies in the foregoing theorems of centres of gravity, since each reader will readily discover them for himself; but I will observe, in general, that the vagueness of the ideas of the Arab physicists respecting force, mass, and weight, a vagueness which is the principal cause of these inaccuracies, seems to have troubled them very little, for our author is no where at the pains to establish a distinction between those three ideas. But the ideas of

the Arab philosophers with regard to gravitation are, in my opinion, much more remarkable; I will not call it universal gravitation, for our author expressly exempts the heavenly bodies from the influence of this force (see Chapter Fifth, Sect. First, 1.), but terrestrial gravitation. That this great law of nature did not present itself to their minds in the form of a mutual attraction of all existing bodies, as Newton enunciated it five centuries later, is quite natural, for at the time when the principles exhibited by our author were brought forward, the earth was still regarded as fixed immovably in the centre of the universe, and even the centrifugal force had not yet been discovered. But what is more astonishing is the fact that, having inherited from the Greeks the doctrine that all bodies are attracted toward the centre of the earth, and that this attraction acts in the direct ratio of the mass, having moreover not failed to perceive that attraction is a function of the distance of the bodies attracted from the centre of attraction, and having even been aware that, if the centre of the earth were surrounded by concentric spheres, all bodies of equal mass placed upon those spherical surfaces would press equally upon the same surfaces, and differently upon each sphere—that, in spite of all this, they held that weight was directly as the mass and the distance from the centre of the earth, without even suspecting, so far as it appears, that this attraction might be mutual between the body attracting and the bodies attracted, and that the law as enunciated by them was inconsistent with the principle which they admitted, that the containing surface of a liquid in equilibrium is a spherical surface. Many geometricians of the first rank, such as Laplace, Ivory, Poisson, and others, have endeavored to establish the consequences of an attraction which should act directly as the distance from the centre of attraction; thus Poisson says:* "Among the different laws of attraction, there is one which is not that of nature, but which possesses a remarkable property. This law is that of a mutual action in the direct ratio of the distance, and the property referred to is this, that the result of the action of all the points of a body upon any one point is independent of the form and constitution of that body, whether homogeneous or heterogeneous, and is the same as if its whole mass was concentrated in its centre of gravity." Farther on, he shows that under the influence of this law the containing surfaces of a revolving liquid are ellipsoid or (with sufficient velocity) hyperboloid; the latter form being possible as a permanent figure only when the liquid is contained within a vessel. It is thus seen that none of the immediate effects of an action in the direct ratio of the distance were of such a character as to set the Arab philosophers on their guard against the consequences of their law of terres-

* Traité de Mécanique, 2de édition, ii. 550-553.

trial gravitation, for they had not the means of arriving at these conclusions. On the other hand, the principle of Archimedes, and the suspicion which they had of the different density of the atmosphere at different heights, taught them that the farther a body was removed from the earth's surface, and consequently from its centre, the less of its weight it would lose from the effect of the medium, that is to say, the heavier it would become; they did not, therefore, hesitate to admit the direct ratio of the distance. It is evident that the Arabs admitted the heaviness of the air, and even that they had, so to speak, discovered the means of estimating it, for they say that a given body loses less of its weight in a rarer than in a denser atmosphere; but in all probability they never made application of this means to ascertain the weight of a volume of air at different altitudes. Finally, neither the Greeks nor the Arabs, so far as appears, were in possession of any positive demonstration of the principle according to which a liquid in equilibrium takes the form of a sphere, but they admitted it as an evident principle, founded on the spherical form of the surfaces of great sheets of water. Upon the whole, it seems to me allowable to believe that the Arabs had one great advantage over the ancients with respect to the study of nature; this, namely, that they were to a much less degree than their predecessors in civilization bent upon fitting the facts observed into artificial systems, constructed in advance, and that they were vastly more solicitous about the fact itself than about the place which it should occupy in their theory of nature.

I shall make no extracts from the sixth chapter, which presents nothing at all worthy of note, but shall pass directly on to the seventh chapter.

It reads as follows, in the original and translated:

الباب السابع

في صنعة مقياس المايعات في الثقل والخفة والعمل به للحكيم فوفس الرومي

قد تبين مما تقدم من المسايل ويأتي بعده من امر نسب اثقال الاجرام ان نسبة حجم جرم كل ثقيل الى حجم جرم اخر ثقيل على التوالي اذا اسوتي وزنهما في الهواء كنسبة الثقل الى الثقل على خلاف التوالي في الماء واذا

CHAPTER SEVENTH.

Mechanism of the Instrument for measuring Liquids, as to Heaviness or Lightness, and Application of it, according to the Philosopher Pappus the Greek.

It is evident, from the theorems already stated, and from what is to be presented respecting the relations between the gravities of bodies, that the relation of any volume of a heavy body to any volume of another heavy body, in direct ratio, when the two weigh alike in air, is as

صارت هذه المقدمة مسلمة فيستخرج بقوتها آلة تتبين لنا نسب زنة
جميع الرطوبات بعضها الى بعض باهون سعى اذا استوت اجرامها فى الحجم
حكما وقدر خفتها بعضها عند بعض وتنفع جدا فى الاشياء التى تصلح
لصحة ابدان الناس من غير استعمال صنجات وميزان فنذكر فيه تقديرها
والتخطيط عليها واستخراج قانون لوضع الحساب والحروف عليها والعمل بها
والبرهان على ذلك وهو يشتمل على ستة فصول

الفصل الاول

فى تقدير الآلة

ان طول هذه الالة التى شكلها شكل اسطوانة مقدار نصف ذراع اليد وعرضه
قدر عرض اصبعين او اقل منه وهى من نحاس مجوفة غير مصمتة مخروطة
بالسهر اخف ما يكون منه ولها قاعدتان من الطرفين جميعا مشبهتان بدفين
خفيفين وقد هندمت عليه بالسهر على احكم ما يكون من العمل وفى
سطح احدى القاعدتين الداخل رصاص قد خرط معه بالسهر شكله شكل

the relation of gravity to gravity, inversely, [when the two are weighed] in water. The force of this fundamental principle, once conceded, leads to the construction of an instrument which shows us the exact relations in weight of all liquids, one to another, with the least labor, provided their bodies are of the same volume, definitely determining the lightness of one relatively to another; and which is very useful in respect to things concerning the health of the human body; and all this without resort to counterpoises or balance. We shall, therefore, speak of the construction of this instrument, the marking of lines upon it, and the development of a rule for the putting upon it of arithmetical calculation and letters [expressive of numbers]; also, of the application of the instrument, and of its basis of demonstration. This will occupy six sections.

Section First.

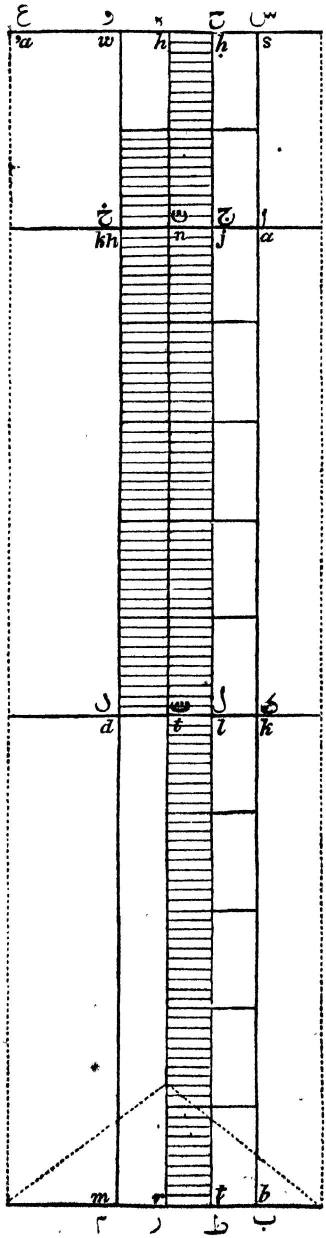
Construction of the Instrument.

The length of this instrument, which is cylindrical in shape, measures half a hand-cubit; and the breadth is equal to that of two fingers, or less. It is made of brass, is hollow, not solid, and the lighter particles of brass are carefully turned off by the lathe. It has two bases, at its two ends, resembling two light drum-skins, each fitted to the end, carefully, with the most exact workmanship; and on the inner plane of one of the two bases is a piece of tin, carefully fitted to that plane by the lathe, shaped like a tunnel, the base of which is the drum-skin itself.

صورة مقياس المايعات لفوفس الرومى

Form of Pappus the Greek's Instrument for Measuring Liquids.[6]

between *sb* and *hr*.	سطر العدد صاعدا Ascending Line of Numbers.
between *wm* and *hr*.	شعيرات المقياس نازلا Descending Round-point[7] Numbers of the Instrument.
akh.	خط الاستواء للاعتدال Equator of Equilibrium.
above *akh.*	الجانب الاخف Lighter Side.
below *akh.*	الجانب الاثقل Heavier Side.
along the line of descending numbers.	الاجزاء المختلفة المطلوبة وبقدرها يكون وزن المايع Different Part-numbers sought for, determining the Weight of the Liquid.
on the cone at the lower end of the instrument.	المخروط المعمول من الرصاص Cone made of Tin.
above the cone.	نسبة البعد الى البعد من القاعدة على التوالى كنسبة شعيرات البعد التالى الى شعيرات البعد الاول على التكافى The Relation of Distance to Distance, successively, from the Base, is, by an Inverse Ratio, as the Round-point Numbers of the Second Distance to the Round-point Numbers of the First Distance.



صنبوری وقاعدته ذلك الدف بعينه حتى اذا وضعت الالة فى رطوبة فى
حوض او اناء قامت عليه قياما منتصبا ولا تميل الى جانب

الفصل الثانی

فى التخطيط عليها

فتخرج اولا خطا فى طول الاسطوانة كلها وهو ضلعها عليه ساب وليبقى فى
اعلى الاناء فوق هذا الخط شئ يسير مقدار سدس قامتها او اقل مما يلى سع
على قاعدة اس وتخرج خطوطا اخر موازية لخط اب وهو خط رح وم حط
اخراجا الى حد نذكره وتنصف خط اب على ك وتجعل كل واحد من
خطوط مد تر لط مثل كا وتضع على نقطة ك ت د ل مسطرة مقوسة
على بسط حدبة الاسطوانة وتخط عليها دايرة وكذلك على نقط
اجنخ دايرة اجنخ وتسميها خط الاستواء للاعتدال وما فوقه هو
جانب اخف الاثقال وما تحته[a3] جانب الاثقل منها ثم تقسم خط اب
بعشرة اقسام للجمل وتخط على نقط الاقسام قسيا على خطى نر واب
وتقسم ما بين كل قسمين بعشرة اقسام من خط نر فتقسم خط نر بماة

The instrument being thus made, when put into liquid in a reservoir or vessel, it stands upon it in an erect position, and does not incline any way.

Section Second.

Marking of Lines upon the Instrument.

You draw, in the first place, lengthwise, along the whole cylinder, a line *sab*, forming its side; and let the upper part of this line remain above [water] in the vessel, namely, a small piece measuring a sixth of the height of the cylinder, or less, *as*, making a part of the line [*sab*] contiguous to the line of one of the bases, *s'a*. You also draw other lines parallel with the line *ab*, namely, the lines *rh*, *wm*, *ḥṭ*, extending to the limit [*s'a*] mentioned. Moreover, you bisect the line *ab* at *k*, and lay off each of the lines *tr*, *md*, *lṭ*, equal to *ka*, and over the points *k*, *t*, *d*, *l*, you place a bent ruler, fitted to the bulge of the cylinder, and draw a circular line over those points; and, in like manner [after laying off the lines *jl*, *tn*, *khd*], you draw, over the points *ajnkh*, a circle *ajnkh*, which you call the equator of equilibrium. That part of the instrument above the equatorial line is the side of lighter gravities [than that of water], and that part below the same is the side of heavier gravities.

Afterwards, you divide the line *ab* into ten parts, for number-letters, and over the points of the several parts you make stripe-like arcs, resting upon the lines *nr* and *ab*; and you divide the distance between each two parts into ten parts, on the line *nr*, so that the line *nr* is divided

قسم اقساما متساوية فتصل بينها وبين خط طج قسيا صغارا متساوية الابعاد فتكون موازية لدايرتى القاعدتين ولتكتب فى السطوح التى فيما بين خطى اب طج حروف الجمل مبتديا من عند ب نحو آ ونسميها سطر العدد المستوى

الفصل الثالث

فى استخراج حساب القانون ووضع اجزاء القياس على الالة

فلنتبين الان كيف يوجد جميع الاعداد التى تدلّ على اوزان الرطوبات ونفرض اولا اناء موهوما مطلقا مثل الدورق يسع فيه من الماء خاصة مأة مثقال او مأة درهم او استار او غيرها للحوالة اليه وجعلنا قامة الالة مأة عدد بحساب الماء خاصة. فاذا اردنا تركيب الجدول ووضع اجزاء القياس فيه ضربنا المأة فى المأة فيصير عشرة الف حفظناه وهو المال المقسوم ابدا فاذا اردنا حصّة جزء جزء من سطر العدد المثبت على الالة فانا نأخذ ذلك الجزء من سطر العدد ونقسم عليه عشرة الف ابدا ونثبت الخارج

into a hundred like parts. Then you connect the hundred points of that line with the line *tj*, by small arcs at even distances one from another, which are consequently parallel with the circles of the two bases; and you are to write on the surfaces [divided off] between the two lines *ab* and *tj* the [appropriate] number-letters, beginning at *b* and proceeding towards *a*, which make what we call the line of even number.

Section Third.

Arithmetical Development of a Rule for the Proportioned Part-numbers [indicating Specific Gravities], and Putting of them upon the Instrument.

You are now to understand how to find all numbers indicating the weights of liquids. In the first place, we fix, in imagination, upon any vessel whatever, as, for example, the daurak, capable of containing [a weight of] water equal to a hundred mithkâls, or a hundred dirhams, or istârs, or any thing else, at our pleasure; and we put down, for the height of the instrument [to the water-line], one hundred numbers, corresponding to the quantity of water assumed. Then, when we wish to make up a table, putting into it the proportioned part-numbers, we multiply 100 by 100, producing 10,000, which we keep in mind, it being the sum to be constantly divided; and if, then, we wish to obtain the proportional for each part of the line of numbers marked upon the instrument, we take [the number of] that part, from the line of numbers, and divide 10,000 constantly by it, and the quotient of the division is set down, opposite to [the number of] that part, in the table of part-numbers and fractions of part-numbers. But that portion of the

من القسمة بازاء ذلك الجزء فى الجدول من الاجزاء وكسورها فما كان من سطر العدد دون المأة فهو حساب الرطوبة التى هى اثقل من الماء وبرهان هذا الحساب يأتى بعده ويشير اليه ابو الريحان فى رسالته اشارة والفضاء الذى فوق خط الاستواء ومن سطر العدد ما هو فوق المأة فهو للرطوبة التى هى اخفّ من الماء نحو الدهن او ما شاكله وقد اكتفينا من سطور العدد فيما بين ن الى قى اذ لا يحتاج فى هذه الالة الى ما هو اكثر واقلّ منهما وهذه صورة جدول القانون واذا اردنا اثبات اجزاء القياس على الالة فانا نرسم بان ا كل جزء من اجزاء سطر عدد الالة التى هى من ا الى قك ما يخصّها من الجدول على خط هر احاد الاجزاء وعلى خط وم خمساتها[63] وعشراتها ونصل فيما بينهما كما ذكرناه بالمسطرة المنحنية من قى الى ن ونبتدى بوضع حروف الجمل من جانب ب نحو ا فما وقع منها فوق خط الاعتدال فهو مقدار الرطوبة الخفيفة وما تحته فهو علامة الرطوبة الثقيلة مضافتان الى ثقل الماء

line of numbers below 100 is the basis of calculation for liquid heavier than water. [So that, for liquids lighter than water, we must have numbers above 100 to calculate upon.]

The basis of demonstration upon which this calculation rests will be stated hereafter; 'Abu-r-Raiḥân alludes to it in his treatise.

So much of the instrument as is above the equator [of equilibrium], and so much of the line of numbers as is above 100, pertains to liquid lighter than water, such as oil and the like. [In our table] we have contented ourselves with lines of numbers from 50 to 110, inasmuch as this instrument does not require to have upon it [for the calculation of specific gravities] numbers either greater than the one or less than the other of the two.

The rule drawn out in a tabular form follows presently.

When we wish to mark the proportioned part-numbers upon the instrument, we set the units of the part-numbers on the line *h r*, and their fifths and tenths on the line *w m*, in such manner that the [proportioned] number-letter of each of the parts of the line of numbers on the instrument, from 1 to 120, shall be just what the table makes it; and with a bent ruler, in the mode spoken of, you make lines of connection between *h r* and *w m* from 110 to 50. We begin with placing the number-letters [derived from the table] on the side of *b*, and proceed towards *a*; but those of them which come above the line of equilibrium constitute the measure for light liquid, and those below that line are the standard for heavy liquid — both being relative to the gravity of water.

جدول حساب القانون

سطر العدد	اجزاء	دقايق	سطر العدد	اجزاء	دقايق
قی	ص	ند	ف	قكه	
قط	صا	مه	عط	قكز	له
قح	صب	له	عح	قكح	يب
قز	صج	كز	عز	قكط	نج
قو	صد	كا	عو	قلا	له
قه	صه	يد	عه	قلج	ك
قد	صو	ط	عد	قله	ح
قج	صز	ه	عج	قلز	
قب	صح	ب	عب	قلح	ند
قا	صط	ا	عا	قم	نا
ق	ق		ع	قمب	نا
صط	قا	ا	سط	قمد	نو
صح	قب	ب	سح	قمز	ج
صز	قج	و	سز	قمط	يه
صو	قد	ی	سو	قنا	ل
صه	قه	يه	سه	قنج	نا
صد	قو	كج	سد	قنو	يه
صج	قز	لا	سج	قنح	مد
صب	قح	مب	سب	قسا	يز
صا	قط	ند	سا	قسج	نو
ص	قيا	ز	س	قسو	م
فط	قيب	كا	نط	قسط	ل
فح	قيج	لح	نح	قعب	كه
فز	قيد	نز	نز	قعه	كو
فو	قيو	يز	نو	قعح	لد
فه	قيز	لط	نه	قفا	مط
فد	قيط	ج	ند	قفه	يا
فج	قك	كط	نج	قفح	م
فب	قكا	نز	نب	قصب	يح
فا	قكج	كح	نا	قصو	ه
			ن	ر	

Table of Calculation by the Rule.[8]

Line of Numbers.	*Parts.*	*Sixtieths.*	*Line of Numbers.*	*Parts.*	*Sixtieths.*
110	90	54	80	125	
109	91	45	79	127	35
108	92	35	78	128	12
107	93	27	77	129	53
106	94	21	76	131	35
105	95	14	75	133	20
104	96	9	74	135	8
103	97	5	73	137	
102	98	2	72	138	54
101	99	1	71	140	51
100	100		70	142	51
99	101	1	69	144	56
98	102	2	68	147	3
97	103	6	67	149	15
96	104	10	66	151	30
95	105	15	65	153	51
94	106	23	64	156	15
93	107	31	63	158	44
92	108	42	62	161	17
91	109	54	61	163	56
90	111	7	60	166	40
89	112	21	59	169	30
88	113	38	58	172	25
87	114	57	57	175	26
86	116	17	56	178	34
85	117	39	55	181	49
84	119	3	54	185	11
83	120	29	53	188	40
82	121	57	52	192	18
81	123	28	51	196	5
			50	200	

الفصل الرابع

فى تعيين مقدار زنة الرصاص

ويحتاج ان يكون مقدار الرصاص الذى ذكرناه الشبيه[c3] بالصنبورة الذى قاعدته[d3] بم على سطحها الداخل مقدارا اذا وضع ميزان الرطوبة فى الماء وقف عليه وقوفا مستويا ورسب من غير ان تتحرك الرطوبة ولا الميزان حتى يصل الى خط الاستواء للاعتدال الذى عليه وزنه المفروض كما فى مثالنا للماء ق ويستعمل فى ذلك التجربة فاما ان يزيد فى الرصاص او ينقص منه حتى يقف على ما قلنا وتجعل النقصان او الزيادة مخروطا بالسهم حتى يكون السهم الذى ينوم للاسطوانة مستويا موزونا فاذا استوى سطح الماء مع خط الاستواء فقد تمت الالة وهذا لفرض الرصاص يختص بماء نهر بلد وواد معروف نحو جيحون او الفرات او غيرهما بقياس ساير المياه اليه خفة وثقلا ويمكن ان نحول من ماء الى ماء اخر بتغيير ثقل الرصاص ورصده فليحفظ هذا

Section Fourth.

Specification of the Proportion in Weight of the Piece of Tin.

It is necessary that the piece of tin which has been mentioned, the tunnel-like thing upon the base *bm*, on the inner plane of that base, should be of such proportion [in weight] that the liquid-balance, when put into water, stands even upon it, and sinks, without any agitation, either of the liquid or of the balance, until the equator of equilibrium is reached, upon which one's determined weight of the liquid is marked, as, for instance, the 100 for water in our diagram. In order to determine this proportion, experiment is resorted to; for the tin is either too heavy or too light, until the motion of the instrument is arrested at the line spoken of; and you carefully reduce the deficit, or the excess, [in the weight of the tin,] by the lathe, until the cylinder, being of the allotted size, is evenly balanced. When the surface of the water is even with the equator [of equilibrium], the instrument is finished. So much for the determination of the proportion of the piece of tin, adapted to water from some known stream of a city or valley, such as the Jaiḥûn or the Euphrates, or others — that being taken as the standard for all waters, as to lightness or heaviness; and we may change from one water to another by varying the weight of the piece of tin, and making observations thereupon. Let this, then, be kept in mind.

Section Fifth.

Knowledge of the Application of the Instrument.

This instrument is such that, when cast into a liquid not having consistence, it sinks therein without hindrance; and if you hold it up erect,

الفصل الخامس

فى معرفة العمل بها

وهذه الآلة اذا طرحت فى شىّ من الرطوبات غير جامد يمكنها ان تغوص فيه بلا مانع وان تحملها منتصبة غير مايلة دلّت على وزن تلك الرطوبة بالشىّ المرسوم من اجزاء القياس وهى الاجزاء المختلفة المطلوبة على الخط الذى يغوص ان يكون مع بسيط الرطوبة ان عرض ان يكون الخط عليه او بالقرب منه ونحفظ عددها الموجود ونقول ان ملاء الدورق الموهوم من تلك الرطوبة رسما مثل العدد المحفوظ مقيسة الى المأة التى هى زنة مقدار الماء الذى يسع فيها كما العدد المحفوظ الى ثقل الماء[e3] وعلى هذا اذا قسنا ماء بلد اخر اليه فظهر الطفهما واخفهما وزنا ان اتفق سطح ماء على اقلّ من و فذلك الماء الطف من ماء النهر المخصوص وان كان اكثى منه اى فى جانب الاثقل فهو اثقل بقدر الشعيرات نسبة الى المأة وان اشتبه علينا عدد الشعيرات فلا يشتبه علينا سطر العدد لنساوى اعداده قسمنا على ملتقى الماء منه ابدا عشرة الف فما خرج من القسمة فهو عدد الشعيرات المطلوبة وذلك ما اردنا ان نذكر

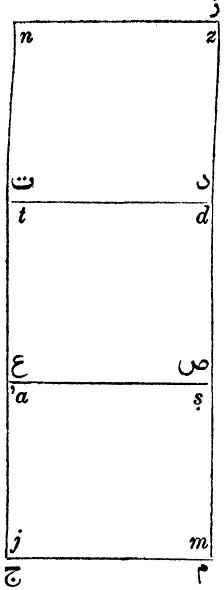
not inclined, it shows the weight of that liquid by some proportioned part-number, among the different part-numbers looked for, marked upon the submerged line, provided that number is even with the level surface of the liquid, so that the line of submergence is upon it, or nearly so. The number found for the liquid in question you keep in mind, and you say that so much of that liquid, with its mark according to the number kept in mind, as would fill the imagined daurak̦, is proportioned to 100, the weight of an equivalent volume of water, as the number kept in mind is to the specific gravity of water.

We proceed in the same manner when we compare the water of another country with that of the stream fixed upon; and thus it is made to appear which of the two is the rarer and lighter in weight. If a surface of water coincides with any line of less number than *kh*, that water is rarer than water of the stream fixed upon; and if it exceeds *kh*, that is, comes on the side of greater gravity, it is heavier, by the measure of the round points [counted to the surface], relatively to 100.

Should we be unable to distinguish the number of the round points, the line of even numbers is in plain sight. By [the number which marks] the point of coincidence on this line with the water we divide, constantly, 10,000; and the quotient of the division is the number of the round points looked for. This is what we wished to state.

الفصل السادس

فی البرهان علی ما ذکرناه



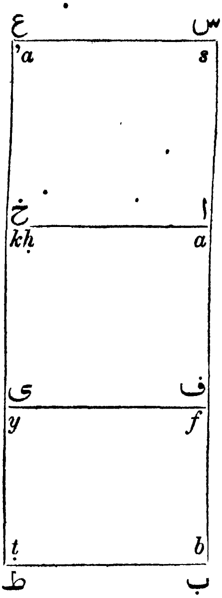
يجعل الاسطوانة نم ولتوضع على شئ من الرطوبات
تنحدر فيها على استواء وانتصاب حتى تصل الى خط
تد واما فى الرطوبة الكثيرة الثقل فلتنحدر حتى
تصل الى عص فيكون كل واحد من خطى تد عص
خطين محيطين بدايرتين متوازيتين وموازيين
لقاعدتى الاسطوانة فيكون على بسيط الرطوبة فاقول
ان نسبة خط عج الى ضلع جت كنسبة وزن الرطوبة
الخفيفة الى وزن الرطوبة الثقيلة فلان نسبة خط عج
الى خط جت كنسبة اسطوانة عم الى اسطوانة
تم ونسبة الرطوبة الخفيفة التى يرتفع ويغرق فيها
عم المساوية لعظم الاسطوانة الى المساوية فى عظمها
لاسطوانة تم اذا كانت الرطوبة واحدة فى كنسبة
خط عج الى خط جت ولكن الرطوبة التى ذكرنا المساوية لاسطوانة

Section Sixth.

is of Demonstration to the Foregoing Statement.[9]

Let the cylinder *nm* be made, and set upon some liquid into which it drops down, even and erect, until the line *td* is reached; and, on the other hand, [let it be put] into some liquid of great gravity, so that it descends [only] until the line *'aṣ* is reached. Accordingly, each of the two lines *td* and *'aṣ*—two lines circling round the cylinder, parallel with each other, and parallel with the two bases of the cylinder—rests upon the level surface of the liquid. I say, then, that the relation of the line *'aj* to the margin *jt* is as the relation of the weight of the light liquid to the weight of the heavy liquid. For, the relation of the line *'aj* to the line *jt* is as the relation of the cylinder *'am* to the cylinder *tm*; and so much of the light liquid, in which *'am* is held up and immersed, as is equal in bulk to that cylinder, bears the identical relation to so much of the same liquid as is equal in bulk to the cylinder *tm*, which the line *'aj* bears to the line *jt*. But [that volume of] the liquid mentioned which is equivalent to the cylinder *tm*, equals, in weight, [a volume of] the liquid having more gravity equivalent to the cylinder *'am*; because these two cylinders [of liquid] are each of equal gravity with the whole cylinder *nm*—as Archimedes has already explained in the first lecture of his book on the sustaining of one thing by

ى مساوية فى وزنها للرطوبة المساوية لاسطوانة عم التى هى اثقل لان
حد منهما[f3] مساو لثقل اسطوانة نم كلها وقد
ذلك ارشميدس فى المقالة الاولى من كتابه فى حمل
ماء بعضها بعضا ونسبة عج الى جت كنسبة
وزن الرطوبة التى مقدارها مثل اسطوانة عم من
الرطوبات الخفيفة[g3] الى وزن الرطوبة المساوية لاسطوانة
عم بعينها من الرطوبات[h3] الثقيلة وذلك ما اردنا ان
نبيّن وان قد تبين هذا فانا نرجع الى صورة الالة
ونقول انه ان وضع رطوبة سط فى شئ من الرطوبات
وضعا مستويا غير مايل ورسب حتى يصل الى خط
اخ فان وزن دورق من تلك الرطوبة بمقدار اجزاء خط
اخ وكذلك اذا رسب فى رطوبة ثقلى[i3] حتى يقف على
خط فى فوزنها بمقدار اجزاء خط فى فنسبه



خط اب الى خط بف هى كما بيّنا قبل نسبة وزن الرطوبة التى رسب
فيها الى خط اخ الى وزن الرطوبة التى رسب فيها الى فى بالتكافى[j3]
فنسبة وزن الرطوبة التى رسب فيها الميزان الى خط فى[k3] كنسبة العدد
الذى على خط فى الى العدد الذى على خط اخ والعدد الذى على

another—and the relation of *'aj* to *jt* is exactly as the relation which the weight of the light liquid, equivalent in volume to the cylinder *'am*, bears to the weight of the heavy liquid, equivalent in volume to the cylinder *'am*; which is what we wished to explain.

This having been made clear, we go back to the figure of the instrument, and say that, if the cylinder *st* is put into any liquid, in an even position, not inclined, and it sinks until the line *akh* is reached, the weight of a daurak of that liquid is according to the measure of the part-numbers at the line *akh*; and so, when it sinks, in a liquid of more gravity, [only] until the line *fy* is reached, the weight of that liquid is according to the measure of the part-numbers at the line *fy*. For, the relation of the line *ab* to the line *bf*, agreeably to the preceding explanation, is the relation of the weight of the [lighter] liquid in which the cylinder sinks to *akh* to the weight of the [heavier] liquid in which it sinks to *fy*, inversely. But the relation of the weight of the liquid in which the balance sinks to the line *fy* [to the weight of the lighter liquid], is the same as the relation of the number upon the line *fy* to the number upon the line *akh*; and the number upon the line *fy* is the

خط فى هو وزن الدورق المطلوب من الرطوبة التى يرسب فيها ميزان
الرطوبة الى خط فى والعدد المرسوم على خط اخ هو وزن الدورق
المفروض مأة من الرطوبة التى يرسب فيها ميزان الرطوبة الى اخ وذلك
ما اردنا ان نبيّن تمّ باب مقياس المايعات لفوفس الرومى وتمت المقالة الاولى[13]

looked for weight of a daurak of that liquid in which the liquid-balance sinks to *fy*; while the number marked upon the line *akh* is the weight of a daurak with the determined 100 [mithkâls, dirhams, istârs, or the like] of that liquid in which the liquid-balance sinks to *akh*; which is what we wished to explain.

The chapter on Pappus the Greek's instrument for measuring liquids is ended; and herewith ends the first lecture.

The substance of this demonstration, which our author states in a somewhat intricate manner, may be presented as follows.

A floating body always displaces a volume of liquid equal in weight to the entire weight of the body itself. The liquid acts upward with a force equivalent to this weight, and, the body acting in a contrary direction with the same force, equilibrium is maintained. If afterwards the same body is plunged into a liquid less dense than the former, the part of it which is submerged will be greater than when it was immersed in the denser liquid, because the volume of the rarer liquid required in order to weigh as much as the floating body will be greater. The absolute weight of these two bodies being the same, their specific gravities will be in the inverse ratio of their volumes; that is, $g : g' :: v' : v$; g and g' being the specific gravities of the two bodies, and v and v' their volumes. The most interesting circumstance connected with the statement of these principles is that the author professes to have derived it from the first chapter of a work of Archimedes, which he describes as فى حمل الاشياء بعضها بعضا "on the sustaining of one thing by another," and which is probably the same with his treatise περὶ τῶν ὕδατι ἐφισταμένων or περὶ τῶν

I have copied the figure of the areometer of Pappus as given by our author, with the corrections required by his description of it. One may easily perceive that the instrument is nearly identical with the volumeter of Gay-Lussac, and that it was provided with two scales, the one with its numbers increasing upwards, to indicate the volume submerged in liquids of different density, the other with its numbers increasing downwards, to show the specific gravities corresponding to those submerged volumes. The table called "table of calculation by the rule" merely repeats the same thing. Let us take, for example, the line of the first scale marked 88. We find in the table that the

line of the second scale corresponding to this division is 113 and 38 sixtieths; or, expressing the latter fraction by decimals, 88 corresponds to 113.63333+. Now it is clear that the specific gravity of water, taken as the unit, will be to the specific gravity of a liquid into which the areometer sinks to 88, as 88 to 100; the specific gravity of the latter will accordingly be 1.1363636+, or, if multiplied by 100, 113.63636+, which differs from the figure adopted by our author by 0.00303, or a fifth of a sixtieth, a fraction of which his table makes no account. So also 93, according to our author, corresponds to 107.51666+, and according to us, to 107.526881+, the difference of which is 0.010215+, or six tenths of a sixtieth; and so on. From this it appears, also, that by adopting the method of sixtieths our author gained the advantage of being able to make the figures in his table fewer, without affecting thereby the thousandths of his specific gravities. In order to understand why he supposes that the limits 50 and 110 are more than sufficient for all possible cases, I would remark that, as we shall see farther on, the Arabs at this period were acquainted with the specific gravities of only seventeen liquids, besides water, which they took for their unit, and mercury, which they classed among the metals, and not among the liquids. In this series, the heaviest liquid was, in their opinion, honey, of which the specific gravity, being 1.406, fell between 71 and 72 of the first scale of the areometer; the highest was oil of sesame, having a specific gravity of 0.915, which corresponded on the areometer to the interval between 108 and 109; while the table gives in addition specific gravities from 2 to 0.902.

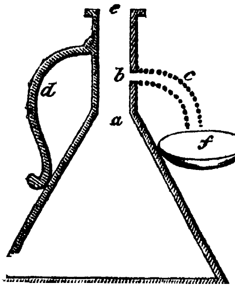
The table of contents will have already excited the suspicion that the second lecture of the work, treating of the steelyard and its use, would be found to contain only elementary matters, of no interest. In truth, our author exhibits in the first chapter the opinions of Thâbit Bin Ḳurrah respecting the influence of different mediums upon the weight of bodies transferred to them; in the second chapter he reverts to the theory of centres of gravity, and demonstrates that the principle of the lever applies equally to two or three balls thrown at the same moment into the bottom of a spherical vase;[10] the third chapter contains a recapitulation of what had been already demonstrated respecting the parallelism with the plane of the horizon of the beam of a balance when loaded with equal weights; chapters four and five, finally, exhibit the theory, construction, and use of the steelyard.

The third lecture is beyond question the richest of all in results, which it is moreover the easier to exhibit, inasmuch as our author has taken the pains to collect them into a limited number of tables. The first chapter, according to the table of contents, should treat of the relations of the fusible metals, as shown by

observation and comparison. In my manuscript of the Book of the Balance of Wisdom there remain only a few leaves of it, the contents of which cause the loss of the rest to be greatly lamented. Notwithstanding the multiplied errors of the copyist, omissions, and inaccuracies of every kind, which prevent me from giving the text itself, it is possible to perceive what is being treated of, and I shall cite here and there fragments of intelligible phrases, which have guided me in the following exposition. The first of the remaining leaves, after a few unintelligible words, which evidently belong to a phrase commenced upon the preceding leaf, contains a figure representing an instrument devised by 'Abu-r-Raiḥân for the determination of specific gravities. I

صورة الآلة المخروطة لابى الريحان

Form of the Conical Instrument of 'Abu-r-Raiḥân.



a عنقها Neck of the Instrument.

b النقبة Perforation.

c الانبوبة على صورة الميزاب Tube in the Form of a Water-pipe.

d عروتها Handle of the Instrument.

e فم الالة Mouth of the Instrument.

f موضع الكفة Place of the Bowl [of the Balance].

give an exact copy of it,[11] with all the explanations which accompany it. A mere inspection of it will suffice to show that we have here to do with an instrument made for determining the volumes of different heavy bodies immersed in the water which fills a part of the cavity, by means of the weight of the water displaced by these bodies, which is ascertained by conducting it through a lateral tube into the bowl of a balance. The description given by our author of the use of this instrument, which he calls الالة المخروطة لابى الريحان, "the conical instrument of 'Abu-r-Raiḥân," confirms this idea; but he adds that the instrument is very difficult to manage, since very often the water remains suspended in the lateral tube, dropping from it little by little into the scale of the balance: الانبوبة تبقى ممتلئة من الماء شرقة غاصّة به. Capillary action was accordingly known to the Arabs; and our author asserts that 'Abu-r-Raiḥân had ascertained that, if the lateral tube had a circular flexure given it, was made shorter than a semicircle, and was pierced with holes, the water would flow readily through it, no more remaining in the tube than just enough to moisten its inner surface: وكذلك لما خرقت ذلك الجانب من الانبوبة خرقا صار به نسف تلك الثقب

شقا الى ان فرجت وصيرتها ميزابا قالبه اقل من نصف دايرة فحينئذ سلس جريان الماء المنصب عليها ولم يتعلق منه بها الا ما لا بد فى الطباع من البلل الضرورى. 'Abu-r-Raihân understood very well that the size of the neck of this instrument affected the sensibility of its indications, and he says that he would have made it narrower than the little finger, but for the difficulty of removing through a smaller tube the bodies immersed in the water, but that this size was small enough to mark a sensible variation of the level of the water if a single grain of millet were immersed in it: وان جعلناه بحيث وسعه الخنصر من الاصابع ظهر ذلك فيها بالقاء ما يساوى الجاورسة فى الجثة.

In the third section of this chapter, our author gives the results of his experiments with the instrument of 'Abu-r-Raihân to ascertain the specific gravity of the various metals. 1. *Gold.* He says that he purified this metal by melting it five times; after which it melted with difficulty, solidified rapidly, and left hardly any trace upon the touchstone: فبقيت الذهب باذوابته[m3] الحادة خمس مرات حتى عسر ذوبه واسرع جموده وقل بالمحك تشبثه; after that, he made ten trials, to obtain the weight of the volume of water displaced by different weights of the gold, and he found, for a hundred mithkâls of gold, weights varying from 5 mithkâls, 1 dânik, and 1 tassûj, to 5 m., 2 d.: as mean weight, he adopts 5 m., 1 d., 2 t. 2. *Mercury.* Our author begins by saying that this is not, properly speaking, a metal, but that it is known to be the mother of the metals, as sulphur is their father. He had purified mercury by passing it several times through many folds of linen cloth, and had found the weight of a volume of water equal to a volume of a hundred mithkâls of mercury to be from 7 m., 1 d., $1\frac{1}{4}$ t., to 7 m., 2 d., $2\frac{5}{6}$ t.; of which the mean, according to him, is 7 m., 2 d., 1 t. 3. *Lead.* The weights found for a volume of water equal to that of a hundred mithkâls of this metal were from 8 m., 4 d., 1 t., to 9 m.; of which the mean, according to our author, is 8 m., 5 d. 4. *Silver.* This metal was purified in the same manner as the gold, and the weights of the corresponding volume of water were from 9 m., 2 d., 2 t., to 9 m., 4 d., 2 t.; the mean adopted by our author being 9 m., 4 d., 1 t. 5. *Bronze,* an amalgam of copper and tin; the proportion of the two metals is not given: the mean weight which he adopts is 11 m., 2 d. 6. *Copper.* Least weight, 11 m., 4 d., 1 t.; mean, 11 m., 3 d., 1 t. 7. A metal of which the copyist has omitted to give the name: the weights found for it vary from 11 m., 2 d., to 11 m., 4 d., 3 t., their mean being 11 m., 4 d.; this value identifies it with the metal given as brass in the later tables. From these same tables we are able also, by reversing our author's processes, to discover

the mean weights adopted by him for the two metals iron and tin, respecting which no notices are derivable from this part of the manuscript; and for the sake of clearness, and of uniformity of treatment with the other classes of substances given later, we present annexed, in a tabular form, the water-equivalents of the metals, or the weights of a volume of water equal to that of a certain fixed weight of each metal respectively.

Metals.	Weights of a volume of water equal to that of a hundred mithkâls of each metal.			
	Mithkâls.	Dâniks.	Tassûjs.	Reduced to Tassûjs.
Gold,	5	1	2	126
Mercury,	7	2	1	177
Lead,	8	5		212
Silver,	9	4	1	233
Bronze,	11	2		272
Copper,	11	3	1	277
Brass,	11	4		280
Iron,	12	5	2	310
Tin.	13	4		328

For the reduction of these weights to the form of an expression for the specific gravity, and for a comparison of the specific gravities thus obtained with those accepted by modern physicists, the reader is referred to the general comparative table, to be given farther on, at the conclusion of our presentation of this part of our author's work.[12]

الفصل الرابع

فى نسب الثقل بينهما

اذا اتّفق حجماها ولان كل ماء اتّصل بالاثقال فان تكافى الاثقال فى النسبة به تعلقا ولذلك اذا اريد وزن احد هذه الاجرام المساوية فى الحجم لمأة مثقال ذهب ويكن الفضة مثلا لم يكن نسبة وزن ماء الذهب الى وزن ماء الفضة كنسبة وزن جرم الذهب الى وزن جرم الفضة ولكنها تكون كنسبة وزن جرم الفضة الى وزن جرم الذهب بالتكافى فاذا ضرب وزن الذهب

SECTION FOURTH. [Lect. 3, Chap. 1.]

Relations of Gravity between the two [Metals].

When the volumes of the two agree, and because all water-equivalents are related by gravities, the two [water-equivalents of the two metals compared] are related to each other by inverse ratio of gravity. Therefore, in case one desires to ascertain the weight of one of these bodies equivalent in volume to a hundred mithkâls of gold—for example, silver—the relation, in weight, which the water-equivalent of gold bears to the water-equivalent of silver is not as the relation of the weight of the

في وزن مايه وقسم ما اجتمع على وزن ماء الفضة او اى جرم اريد وزنه
لكنا فرضنا الذهب ماة مثقال فمضروبه في وزن مايه لا يتغير عن مقداره
وهو خمس ماة وخمسة وعشرون مثقالا فيجب ان يكون لما نحن فيه
محفوظا حتى اذا قسم على اوزان هذه المياه خرج اوزان اجرامها وقد
فعلنا ذلك واودعناه في هذا الجدول

جدول النتيجة من اوزان مياه الاجرام

الفلزات	اوزان الاجرام المتساوية الجثث			طسايج هذه الاوزان	ارقام طسايجه
	مثاقيل	دوانيق	طسايج		
الذهب	مأية	لا شئ	لا شئ	الفان واربع مأة	٢٤٠٠
الزيبق	احد وسبعون	واحد	واحد	الف وسبعمأة وتسعة	١٧٠٩
الاسرب	تسعة وخمسون	اثنان	اثنان	الف واربعمأة وستة وعشرون	١٤٢٦
الفضة	اربعة وخمسون	لا شئ	اثنان	الف ومأتان وثمانية وتسعون	١٢٩٨
الصفر	ستة واربعون	اثنان	لا شئ	الف ومأة واثنا عشر	١١١٢
النحاس	خمسة واربعون	ثلاثة	لا شئ	الف واثنان وتسعون	١٠٩٢
الشبه	خمسة واربعون	لا شئ	لا شئ	الف وثمانون	١٠٨٠
الحديد	اربعون	ثلاثة	ثلاثة	تسعمأة وخمسة وسبعون	٩٧٥
الرصاص	ثمانية وثلاثون	اثنان	اثنان	تسعمأة واثنان وعشرون	٩٢٢

of gold to the weight of the body of silver, but is as the relation of the weight of the body of silver to the weight of the body of gold, by an inverse ratio. So then, if the weight of the gold is multiplied by the weight of its water-equivalent, and the product is divided by the weight of the water-equivalent of silver, or of any other body of which we wish to ascertain the weight [of an equivalent volume, the desired result is attained]. But we have designated a hundred mithkâls as the weight of the gold, so that the product of the multiplication of that into its water-equivalent is an invariable quantity, namely, 525 mithkâls. That number, then, must be kept in mind, in order to the results which we aim to obtain, until the division of it by these [several] water-equivalents brings out, as quotients, the weights of [equal volumes of] the bodies having the [several] water-equivalents. We have done ac-

Table of Results from Water-equivalents of Bodies.

Metals.	Weights of Bodies equal in Volume.			Weights reduced to Ṭassûjs.	Tassûjs in Numerals.
	Mithkâls.	Dâniks.	Ṭassûjs.		
Gold.	100	0	0	Two thousand four hundred.	2400
Mercury.	71	1	1	One thousand seven hundred and nine.	1709
Lead.	59	2	2	One thousand four hundred and twenty-six.	1426
Silver.	54	0	2	One thousand two hundred and ninety-eight.	1298
Bronze.	46	2	0	One thousand one hundred and twelve.	1112
Copper.	45	3	0	One thousand and ninety-two.	1092
Brass.	45	0	0	One thousand and eighty.	1080
Iron.	40	3	3	Nine hundred and seventy-five.	975
Tin.	38	2	2	Nine hundred and twenty-two.	922

The fifth section is entirely wanting in my manuscript. As regards the sixth section, which is the last one in this chapter, it contains a recapitulation of all that had been before stated respecting the specific gravities of bodies, and may be summed up in the familiar enunciation that the specific gravity of a body is the ratio between its absolute weight and the weight of the volume of water which it displaces.

From this point onward, the condition of the manuscript permits me to resume the citation and translation of longer extracts.

الباب الثانى

فى رصد الجواهر الحجرية وهو فصول

قال ابو الريحان ان هذه الفلزات لم يعرفها الناس الا لانقيادها فى النار لعمل مصالحهم من الاوانى الصابرة على ما لم يصبر عليه غيرها ثم الات الفلاحة واسلحة الحروب وغير ذلك مما لا يستغنى عنه المستعمل بامتلاك الدنيا

CHAPTER SECOND.

Observation of Precious Stones. In several Sections.

"Men prize these metals," says 'Abu-r-Raiḥân, "only because, under the action of fire, they admit of being made into conveniences for them, such as vessels more durable than others, instruments of agriculture, weapons of war, and other things which no one can dispense with who is set to possess himself of the good things of life, and is desir-

الراغب فى زخارفها ثم لم يفضلها بعضها فى الجلالة الا باصطلاحهم على
ثمين الحوائج به ة والقانون فى ذلك قلّة وجود الشئ وطول بقاء الموجود
منه وهذه صفة الذهب وعزّة وجوده وطول بقايه وقلة ظهور السدى فيه من
رطوبة الماء[n3] ونداوة الارض[o3] او البقر او التكلس[p3] من نار والاحتراق[q3] مع
انقياده لقبول الختم المانع ذوى التمويه عن حكايته بغيره ثم حسن منظره
فلولا ان فيه حالة مجهولة الكيفية لما هشّ له الطفل الصغير وبمدّ مدّه من
مهده للقبض عليه ولما تعلل به الصبى عن البكاء من غير ان يعرف له قيمة
او يصلح به حاجة ولما تصالح اهل العالم عليه غير مسالبين فى تحصيله
بالارواح والانفس والاهل والولد والاملاك والاقاصى بكثرة المجتمع الوطر
ولكنهم يبتغون دايمًا ثالث الواديين الى امتلاء الجوف بالتراب ولولا خوفى
الاطبّاء لقلت ان فرح النفس بالذهب واللؤلوء والديباج عند رؤيتها يقلّ
الى تفريحاتها فى المعاجين والنفس لا تسكن حرق الذهب وسحق اللولو

ous of the adornments of wealth. Moreover, the only token by which men show a preference of some of the metals [over others] is their technical use of the letter *h*, stamped upon any precious metal of which articles wanted are made; and in regard to that they are controlled by the rarity of the occurrence of the metal, and the length of time that it lasts; both which are distinctive characteristics of gold." But if, beside the rarity of its occurrence, and its durability, and the little appearance of moisture on it, whether moisture of water or humidity of the earth, or of its being cracked or calcined by any fire, and consumed, together with its ready yielding to the stamp, which prevents counterfeiters from passing off something else for it, and, lastly, the beauty of its aspect—if there is not [beside all these characteristics] some inexplicable peculiarity pertaining to gold, why is the little infant delighted with it, and why does he stretch himself out from his bed in order to seize upon it? and why is the young child lured thereby to cease from weeping, although he knows no value that it has, nor by it supplies any want? and why do all people in the world make it the ground of being at peace one with another, not drawing their swords to fight, though at the sacrifice of the powers of body and soul, of family-connections, children, ground-possessions, and every thing, with even a superfluity of renunciation, for the sake of acquiring that; and yet are ever longing for the third stream,* to stuff their bellies with the dust?

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* There is here an evident allusion to the traditional saying: ولو ان لابن ادم واديين يسيلان من الذهب والفضة لا محالة ابتغى ثالثهما "and if the son of Adam were to possess two flowing rivers of gold and silver, doubtless he would third."

وترميد الابريسم وانما تحزن له فان كانت مقوية للقلب بخاصّيته فسمعا
وتعرض عن التفريح ثم يتلو الذهب الفضة فى الاحوال التى ذكرناها وكذلك
جعل اعواضا عن الحاجات واثمانا للضروريات وليست هذه الصفة بمقصورة
على الذائبة من الاجساد المستنبطة بل تبعدها الى غيرها من الجواهر
الغير الذائبة والياقوت الاحمر فيها نظير الذهب فى عزّة الوجود وصلابة
الجثة وكثرة الماء والرونق ولمعان الحمرة ومصابرة النار ومقاومة اسباب
الفساد وطول البقاء ويتلوه الاصفر والكحلى من انواعه والزمرد والزبرجد
من غير نظاير الفضة ويفوق جميع ذلك فائق اللولو بدليل ظاهر هو ان
رخاوة جسمه وتركّب اكثره من قشور متضاعفة كاضعاف البصل وتلاشيه
بالنار رمادا او عظما رميما وتغير لونه بالطبّ والعطر وامثال ذلك من اسباب
البلى ثم لم يقدح فى قيمته ولم ينقص من ثمنه شيأ وليست عدّة الجواهر
هذه فقط بل يذكر منها اشياء قد فنيت معادنها وتفانى الكاين منها فى

Were it not for my fear of the physicians, I might also say that the soul's gladness at the sight of gold, the fine pearl, and the silk robe, falls little short of its delight in medicinal confections.* Nor does the soul take quietly the grinding up of gold, the pulverizing of the fine pearl, and the reducing of silk to ashes. It is only saddened thereat; for, though by such means alone the heart be strengthened, yet men, so hearing, turn away from the [offered] exhilaration.

Silver is next to gold as respects the peculiarities mentioned, and is, in like manner, made into tenders for things wanted and representatives of value for articles of necessity.

Nor does the description apply only to fusible minerals. On the contrary, you may extend it to substances not fusible. Of these, the red hyacinth† [ruby] is equivalent to gold, on account of the rarity of its occurrence, the hardness of its crust, the abundance of its water, its lustre, the depth of its redness, its bearing of fire, its withstanding causes of injury, and its durability. Next to this come the yellow hyacinth [topaz], that which is [blackish] like collyrium, the emerald, and the chrysolite, which differ [from the ruby] and are equivalents of silver. To all the above named the fine pearl is manifestly inferior, as appears from the softness of its body, its being generally composed of

* Our author evidently alludes, in jest, to the famous معاجين مفرح, "exhilarating confection," of the oriental physicians.

† For want of a better word, we use "hyacinth" in a generic sense in this chapter, to represent the Arabic ياقوت, as applied to all precious stones alike, a word which has no proper equivalent in any European language. See De Sacy's Chrest. Arabe, 2de éd. iii. 464.

ايدي الناس حتى جهلوا الان اعيانها ويظهر فى زمان بعد زمان ما لا يعرف
حتى يعرف مثل هذا الجوهر الاحمر البدخشانى الذى لولا رخاوته وقلة
بقاء الماء فى وجهه لفضل الياقوت فى حسنه وليس بقديم العهد وانما
انشقّ جبله بزلزلة فظهر من اثنائه كالبيضات المنضودة فى مواضع ككور
النار وانكسر بعضها فاشرقت الحمرة من تحتها وعثر عليه الصناع فجمعوه
ولم يهتدوا لمائه وصقل وجهه وجلائه ثم ادّتهم التجارب الى الحجر المعروف
من جهة[r3] الشبيه لونا بالمرقشيشا الذهبانى وتم به امرهم واطّرد المعدن
ويمكن ان يظهر فيما يستأنف من الزمان من تحت الجبال وقرار الانهار
وقعور البحار واضعاف الارض جواهر ذائبة وغير ذائبة غير ما نعرفه الان
ولكنا لا نبيع فيها النقد بالدين ولا نعرض عن معلوم بسبب مجهول لان
الفن الذى خضنا فى اوايله وسعينا لتحصيل الاته وتوطئة مقدماته منته
على تخاليط ذوى العيب والفساد فى النقود والصوغ منها وقد يتناول

pellicles, doubling one upon another, like the coats of an onion, its being reduced by fire to ashes or rotten bone, and its change of color from the action upon it of medicine or perfume, or other like causes of deterioration. Yet one finds no fault with its price, nor at all undervalues it.

The number of the precious stones is not thus exhausted. But suffice it to say, on the other hand, that certain gems are mentioned, of which the mines are no longer found, and the specimens once in the hands of men have disappeared, so that people are now ignorant of what sort they were. There appear, also, from time to time, gems not before known, such as that red gem of Badakhshân, which, were it not for its softness, and that the water of its surface lasts but a little time, would be superior in beauty to the [red] hyacinth, and is no antiquated gem. The mountain containing it was fissured by an earthquake, and the windings of the rent brought to view, here and there, egg-like lumps of matter deposited in layers, resembling balls of fire, of which some were broken, so that a red light gleamed forth beneath where they lay. Lapidaries stumbled upon the gem, and gathered specimens, and, having nothing to guide them respecting [the purification of] its water, and the polishing of its face and making it brilliant, were, after a while, led by experiments to make use of the stone called, on account of likeness of color, the golden marcasite, and with that succeeded; and the mine has yielded abundantly.

It is not impossible that both fusible and infusible substances, now unknown, may be brought to light, at any time, from the undercliffs of mountains, and from the beds of rivers, the depths of seas, and the bowels of the earth. In respect to such, however, we will not barter away ready money for a credit, nor turn from the known for the sake of

الجواهر ابدى التمويه كما يتناول الفلزات بل اكثر وابلغ لقلة اعتياد الاعين اياها وعماها عن الاهتداء لاختيارها فلا يخلو احد فى بلد عن مشاهدة دراهم ولا تجارة عن ممارسة الدنانير ثم اصحاب الجواهر والحلى على عدد يسير فيهم وغير مستعملين لها على الدوام فمن الواجب علينا ان نمهّد للجواهر مثل ما مهدنا للفلزات ان شاء الله تعالى

الفصل الاول

فى ذكر ما حصل لنا فى الجواهر بالالة

ولنعدد اولا ما وقع به الاعتبار ثم نتليه بالمقادير التى حصلت له فالاول اليواقيت ان العامة اذا سمعوا من الطبيعيين فى الذهب انه اعدل الاجساد والبالغ تمام النضج فى غاية الكمال فى الاعتدال اعتقدوا فيه انه متدرج اليها بالمرور على صور ساير الاجساد حتى انه كان ذهبيته اسرفا ثم صار رصاصا ثم نحاسا ثم فضة ثم بلغ الكمال الذهبى ولم يعلموا انهم لم يعنو بذلك الا مثل ما عنوه فى الانسان ووصفه بالكمال والاعتدال فى الطباع والخلقة من غير

the unknown. For I am interested in the subject of which we are investigating the rudiments, and endeavoring to get at the main supports, and to tread upon the foundations, on account of the counterfeitings of those who put in circulation vitiated and spoiled money, and practice adulteration in the goldsmith's art. But precious stones are counterfeited as well as metals, nay, oftener and more successfully, because the eye is little accustomed to them, and wants the guidance of habit in the choice of them; while, on the other hand, no one in any city fails to see dirhams, and no trading is possible without the handling of dînârs. The possessors of precious stones and jewelry are few in number among men, while those who make use of metals are ever to be found. We must, therefore, treat of precious stones as we have treated of metals, if the Supreme God so wills.

Section First.

of the Results which we have obtained, by the [Conical] Instru-', in respect to Precious Stones.

We will first enumerate the precious stones which have been compared, and afterwards exhibit their proportions [of weight], as proved by comparison.

1. *Hyacinths.* When the common people hear from natural philosophers that gold is the most equal of bodies, and the one which has attained to perfection of maturity, at the goal of completeness, in respect to equilibrium, they firmly believe that it is something which has gradually come to that perfection by passing through the forms of all

ان يكون ثورا ثم يحول حمارا ثم فرسا ثم قردا وصار بعد ذلك انسانا
وتوهموا مثله فى انواع الياقوت[e3] فزعموا انه يكون ابيض اولا ثم يسود
ويكهب ويصفر ثم يحمر وقد بلغ النهاية من غير ان شاهدوا اجتماعها فى
معدن واحد ثم توهموا الاحمر من تمام الوزانة والثقل مثل ما وجدوه فى
الذهب ونحن وجدنا للاسمانجونى والابيض فضلا بها فى الثقل على الاحمر
ولم يتفق لى من بعد الاصفر مقدار يجوز ان يعتبر فيه الاعتبارات المتقدمة
ويعتمد امره فيها الثانى اللعل البدخشانى[t3] وكذلك لم يحصل لى من
اصفره ما اعرف فرقا بينه وبين احمره المختار المعروف بپيازكى اى البصلى
الثالث الزمرذ والزبرجد هذان اسمان مترادفان اما على موضوع واحد
واما على موضوعين احدهما معدوم واسم الزمرذ هو الاعمّ ثم شاهدت من
يوقعه على ما دون السلقى او الريحانى المشبع الخضرة الكامل الشفاف

[other metallic] bodies, so that its gold-nature was originally lead, afterwards became tin, then brass, then silver, and finally reached the perfection of gold; not knowing that the natural philosophers mean, in saying so, only something like what they mean when they speak of man, and attribute to him a completeness and equilibrium in nature and constitution — not that man was once a bull, and was changed into an ass, and afterwards into a horse, and after that into an ape, and finally became man. The common people have the same false notion, also, in regard to the species of hyacinth, and pretend that it is first white, afterwards becomes black, then dusky, then yellow, and at last becomes red, whereupon it has reached perfection; although they have not seen these species together in any one mine. Moreover, they imagine the red hyacinth to be perfect in weight and specific gravity, as they have found gold to be; whereas we have ascertained that the celestial species [sapphire][13] and the white [the diamond] exceed the red in gravity. Of the yellow I never happened to have a piece sufficiently large to be submitted to the same reliable comparisons already made with other species.

2. *Ruby of Badakhshân.* I have, in like manner, never obtained such a piece of the yellow species of this gem that I could distinguish it from the choice red, called *piyâzakî*, that is, the bulb-like.

3. *Emerald* and *Chrysolite.* These names [الزمرذ and الزبرجد] are interchangeable, whether applied to one and the same thing, or to two things of which one has no real existence; and the name of emerald is the more common. I have, however, seen a person who gave the name of emerald to all varieties of the mineral excepting the beet-like, or basil-like,[14] which has an equally diffused green hue, and is perfect, transparent, and pure in color; and who denominated the latter chrysolite.

الناصع اللون ويصف هذا بالزبرجد الرابع العقيق الجزع واللازورد
والبلور والزجاج وان لم يكن معدنيا بل مشتركا من حجر او رمل او قلى
فانه من اشباه البلور فلذلك اعتبرناه وسوى هذه الاحجار كالدهنج
والفيروزج والجمست واشباهها لم يمنعنا عن الدهنج الا قلة وجوده بفناء
معدنه وعن الفيروزج غير اختلاطه دايما بما ليس من نوعه من داخله وكل
هذا الضرب من الاحجار غير حظى من الثمن سوى الجزع فللبقرانى منه
قيمة وكذلك ما يتفق فيه صورة حيوان او شكل عجيب وقد ملّ الناس
العقيق حتى لا يستعمل فى فصوص الخواتيم لايدى العامة دون الخاصة
واللازورد مستعمل بسبب الصبغ والنقش الكاين من انواعه الخامس
اللولو ليس اللولو من هذه الجملة وانما هو عظم حيوان وغير متشابه الاجزاء
وقد الحقه حسنه بالياقوت كما الحق الزمرد به حسنه وعزّته معا فاجتمع
اجتماعهما[u3] اليها وما اختلف على شى من الاشياء المقدمة اختلاف المياه
الخارجة باللآلى والزيادات والنقصانات التى وقعت بين الصغار منها والكبار

4. *Cornelian*, *Onyx*, *Lapis Lazuli*, *Crystal*, and *Glass* (this last — although it is not the product of a mine, but, on the contrary, kindred to stones, or sand, or alkali — because it resembles crystal, for which reason we have submitted it to comparison), and precious stones similar to these, such as *Malachite*, *Turquoise*, *Amethyst*, and the like. The malachite [itself], on account of the rarity of its occurrence, from there being no mine of it now known, has been unobtainable; so, too, the turquoise, which, besides, always has within it a mingling of foreign matter. This whole class of stones is not highly prized; excepting the onyx, for a certain value is attached to specimens of this mineral marked with ox-hoof circles,[15] and likewise to those in which there happens to be presented the form of an animal, or some strange shape. Men have been long tired of the cornelian, so that it has ceased to be used as a stone for seal-rings, even for the hands of common people, to say nothing of the great. The lapis lazuli is employed on account of the tinting and variegation of its several species.

5. *The Fine Pearl.* The pearl is not a stone at all, but only the bone of an animal, and not homogeneous in its parts. Yet I associate it with the hyacinth for its beauty, as I join therewith the emerald both for its beauty and its rarity. It therefore comes in here with as good reason as they do. Besides, there is no such difference of opinion respecting the minerals which have been mentioned, as exists in regard to the water-equivalents obtained in the case of pearls; nor have the accessions or losses, as between small and large ones, been recorded — a point on which there is great diversity. What I shall state, as to the pearl, applies to those which are large, full, and rounded.

غير مضبوط وشديد التباين والذى سأذكر منه فانه لكبارها العيون المدحرجة السادس البسذ هذا ايضا نبات وان استحجر كحجر اليهود والسرطان البحرى[v3] وله نوع ابيض اغلظ من الاحمر ومثقوب كله مجذور ولم اعتبره لقلة استعمال الناس اياه على انى سمعت على ان الاحمر اذا قلع كان ابيض ثم يحمر بعد ذلك بملاقاة الهواء اياه وقد ضمنا هذا الجدول

جدول وزن مياه الجواهر على اى وزن كل مأة مثقال هوائية

اسماء الجواهر	اوزان المياه			طساسيج هذه المياه	اقوام طساسيج
	مثاقيل	دوانيق	طساسيج		
الياقوت الاسمانجونى	خمسة وعشرون	واحد	اثنان	ستمأة وستة	٦٠٦
الياقوت الاحمر	ستة وعشرون	لا شئ	لا شئ	ستمأة واربعة وعشرون	٦٢٤
البدخشانى[w3]	سبعة وعشرون	خمسة	اثنان	ستمأة وسبعون	٦٧٠
الزمرد	ستة وثلثون	اثنان	لا شئ	ثمانمأة واثنان وسبعون	٨٧٢
الازورد	سبعة وثلثون	واحد	لا شئ	ثمانمأة واثنان وتسعون	٨٩٢
اللؤلؤ	ثمانية وثلثون	ثلثة	لا شئ	تسعمأة واربعة وعشرون	٩٢٤
العقيق	تسعة وثلثون	لا شئ	لا شئ	تسعمأة وستة وثلاثون	٩٣٦
البسذ	تسعة وثلثون	لا شئ[x3]	ثلثة	تسعمأة تسعة وثلاثون	٩٣٩
الجزع والبلور	اربعون	لا شئ	لا شئ	تسعمأة وستون	٩٦٠
الزجاج الفرعونى	اربعون	واحد	لا شئ	تسعمأة واربعة وستون	٩٦٤

6. *Coral.* This is a plant, though petrified, like the Jews' stone[16] and the sea-crab.[17] There is a white species of it, coarser than the red, perforated throughout, and divided; which I have not compared, because men use it but little, and also because I have heard speak as if the red were white when torn off, and became red by exposure to the air.

We have put together the following table.

الفصل الثانى[18]

فى نسب الاوزان للجواهر المتساوية الحجم

وبحسب ما تقدّم من استخراج الاوزان المتساوية الجثث فى الفلزات يعمل
مثله فى الجواهر المتساوية الحجم على ان جثّة كل واحد منها مساوية
لمأة مثقال من الياقوت الكحلى حتى يسلك منه القاصد طريقه الى اى
مقدار فرض له بخواصّ الاعداد الاربعة المتناسبة كما فى هذا الجدول

Table of Weights of the Water-equivalents of Precious Stones, supposing all the Weights in Air to be a Hundred Mithkâls.

Names of Precious Stones.	Weights of Water-equivalents.			Water-equivalents reduced to Ṭassûjs.	Ṭassûjs in Numerals.
	Mithkâls.	Dâniks.	Ṭassûjs.		
Celestial Hyacinth.	25	1	2	Six hundred and six.	606
Red Hyacinth.	26	0	0	Six hundred and twenty-four.	624
[Ruby] of Badakhshân.	27	5	2	Six hundred and seventy.	670
Emerald.	36	2	0	Eight hundred and seventy-two.	872
Lapis Lazuli.	37	1	0	Eight hundred and ninety-two.	892
Fine Pearl.	38	3	0	Nine hundred and twenty-four.	924
Cornelian.	39	0	0	Nine hundred and thirty-six.	936
Coral.	39	0	3	Nine hundred and thirty-nine.	939
Onyx and Crystal.	40	0	0	Nine hundred and sixty.	960
Pharaoh's Glass.[18]	40	1	0	Nine hundred and sixty-four.	964

Section Second.

Relations between Weights of Precious Stones alike in Volume.

By way of correspondence with the computation already given of the weights of equal masses of metals, a similar estimate is [here] furnished relative to precious stones of like volume, supposing that each mass is equal in volume to a hundred mithkâls of the collyrium-like hyacinth; in order that one who would ascertain any proportion [of weight] required may be enabled to do so, through the properties of four mutually related numbers.

جدول اوزان الجواهر المتساوية العظم

اسماء الجواهر	اوزانها اذا ساوت مأة مثقال الياقوت الكحلى فى الحجم			تجنيس الطساسيج	ارقام طساسيجه
	مثاقيل	دوانيق	طساسيج		
الياقوت الاسمانجونى	مأة	لا شئ	لا شئ	الفان واربعمأة	٢٤٠٠
الياقوت الاحمر	سبعة وتسعون	لا شئ	ثلثة	الفان وثلثمأة واحد وثلثون	٢٣٣١
اللعل	تسعون	اثنان	ثلاثة	الفان ومأة واحد وسبعون	٢١٧١
الزمرد	تسعة وستون	ثلاثة	لا شئ	الف وستمأة وثمانية وستون	١٦٦٨
اللازورد	سبعة وستون	خمسة	اثنان	الف وستمأة وثلاثون	١٦٣٠
اللؤلؤ	خمسة وستون	ثلاثة	اثنان	الف وخمسمأة واربعة وسبعون	١٥٧٤
العقيق	اربعة وستون	اربعة	اثنان	الف وخمسمأة واربعة وخمسون	١٥٥٤
البسّذ	اربعة وستون	ثلاثة	واحد	الف وخمسمأة وتسعة واربعون	١٥٤٩
الجزع والبلور	ثلثة وستون	لا شئ	ثلثة	الف وخمسمأة وخمسة عشر	١٥١٥
الزجاج الفرعونى	اثنان وستون	خمسة	واحد	الف وخمسمأة وتسعة	١٥٠٩

Table of Weights of Precious Stones alike in Volume.

Names of Precious Stones.	Weights, when the Volume is equal to a Hundred Mithkâls of the Collyrium-like Hyacinth.			Reduction to Ṭassûjs.	Ṭassûjs in Numerals.
	Mithkâls.	Dâniks.	Ṭassûjs.		
Celestial Hyacinth.	100	0	0	Two thousand four hundred.	2400
Red Hyacinth.	97	0	3	Two thousand three hundred and thirty-one.	2331
Ruby [of Badakhshân].	90	2	3	Two thousand one hundred and seventy-one.	2171
Emerald.	69	3	0	One thousand six hundred and sixty-eight.	1668
Lapis Lazuli.	67	5	2	One thousand six hundred and thirty.	1630

الفصل الثالث

في نسب الاوزان الهوائى الى المائى

رجعنا الى الماء والميزان العدل وقصدنا منه معرفة المقدار الذى يتفاضل به وزن كل واحد من الجواهر المختلفة فى الماء والهواء اذا كانت الكفة التى فيها الجوهر فى الماء فحسب فتزنه فيه بعد وزنه فى الهواء ففى ذلك الوزن عناء شديد لمعرفة الجواهر الحقيقية وتميّزها من الملوّنة وابو الريحان اعرض عن ذكره ويسهل ثبته مما ذكره فى الفصل الاول من هذا الباب وهو انّا نأخذ وزن مائيه المذكور لكل جوهر وننقصه ابدا من مأة مثقال وزنه الهوائى فيبقى وزنه المائى فاثبتنا ذلك فى هذا الجدول

[TABLE CONTINUED.]

Names of Precious Stones.	Weights, when the Volume is equal to a Hundred Mithkâls of the Collyrium-like Hyacinth.			Reduction to Tassûjs.	Tassûjs in Numerals.
	Mithkâls.	Dâniks.	Tassûjs.		
Fine Pearl.	65	3	2	One thousand five hundred and seventy-four.	1574
Cornelian.	64	4	2	One thousand five hundred and fifty-four.	1554
Coral.	64	3	1	One thousand five hundred and forty-nine.	1549
Onyx and Crystal.	63	0	3	One thousand five hundred and fifteen.	1515
Pharaoh's Glass.	62	5	1	One thousand five hundred and nine.	1509

Section Third.

Relations of Air-weights to Water-weights.

We resort again to water and the just balance, and propose thereby to ascertain the measure of the difference between the weight of any one of the several precious stones in water and its weight in air. When the bowl containing the precious stone is once in the water, that is enough—you thus get its weight in water, after having weighed it in air. This is a great help to a knowledge of what are genuine precious stones, and to their being distinguished from those [artificially] colored. 'Abu-r-Raihân does not speak of this matter, but at the same time his statement given in the first section of this chapter facilitates the settlement of it; that is to say, we may take the weight of its water-equivalent [there] stated, for each precious stone, and subtract it constantly from the hundred mithkâls constituting its air-weight, and the remainder will be its water-weight.

Now we have set down these water-weights in the following table.

جدول الاوزان المائية لمأة مثقال هوائية زاده الخازنى

اسماء الجواهر	اوزانها المائية*			تجنيس الطسايج	ارقام طسايجها
	مثاقيل	دوانيق	طسايج		
الياقوت الاسمانجونى	اربعة وسبعون	اربعة	اثنان	الف وسبعمأة واربعة وتسعون	١٧٩٤
الياقوت الاحمر	اربعة وسبعون	لا شئ	لا شئ	الف وسبعمأة وستّة وسبعون	١٧٧٦
البدخشانى[z3]	اثنان وسبعون	لا شئ	اثنان	الف وسبعمأة وثلاثون	١٧٣٠
الزمرد	ثلثة وستّون	اربعة	لا شئ	الف وخمسمأة وثمانية وعشرون	١٥٢٨
اللازورد	اثنان وستّون	خمسة	لا شئ	الف وخمسماة وثمانية	١٥٠٨
اللؤلؤ	احد وستّون	ثلثة[a4]	لا شئ	الف واربعمأة وستّة وسبعون	١٤٧٦
العقيق	احد وستّون	لا شئ	لا شئ	الف واربعمأة واربعة وستّون	١٤٦٤
البسّذ	ستّون	خمسة	واحد	الف واربعمأة واحد وستّون	١٤٦١
الجزع والبلور	ستّون	لا شئ	لا شئ	الف واربعمأة واربعون	١٤٤٠
الزجاج الفرعونى	تسعة[b4] وخمسون	خمسة	لا شئ	الف واربعمأة وستّة وثلثون	١٤٣٦

Table of Water-weights to a Hundred Mithkâls in Air, added by 'al-Khâzinî.

Names of Precious Stones.	Water-weights.			Reduction to Tassûjs.	Tassûjs in Numerals.
	Mithkâls.	Dâniks.	Tassûjs.		
Celestial Hyacinth.	74	4	2	One thousand seven hundred and ninety-four.	1794
Red Hyacinth.	74	0	0	One thousand seven hundred and seventy-six.	1776
[Ruby] of Badakhshân.	72	0	2	One thousand seven hundred and thirty.	1730
Emerald.	63	4	0	One thousand five hundred and twenty-eight.	1528
Lapis Lazuli.	62	5	0	One thousand five hundred and eight.	1508

الفصل الرابع

فى الوصية والاشارة الى اختلاف المياه

وليس الاعتماد على هذه الجواهر كالاعتماد على الاجساد الذائبة فان هذه تواتى الطرق حتى يستوى وضع اجزايها ويفارقها من الهواء ما عسى داخلها فى البواطق والتراب[c4] ثم لا علم لنا بما فى ضمن الاحجار الا ان تشف ويرى ما ورايها فلا يخفى حينيذ ما فى بطونها حتى ان الشك قايم فى قلبى فى خفة الياقوت الاحمر وتخلفه فى الوزن عن الاكهب فان اكهبه واصفره يكون اصم لا يشوبه شىٔ من التراب[d4] او الهواء[e4] او غيره وذلك فى احمره اعز وجودا فان اكثره يكون ذا نفاخات فى وسطه مملوءة الهواء[f4] ومختلط

[TABLE CONTINUED.]

Names of Precious Stones.	Water-weights.			Reduction to Ṭassûjs.	Tassûjs in Numerals.
	Mithḳâls.	Dâniḳs.	Ṭassûjs.		
Fine Pearl.	61	3	0	One thousand four hundred and seventy-six.	1476
Cornelian.	61	0	0	One thousand four hundred and sixty-four.	1464
Coral.	60	5	1	One thousand four hundred and sixty-one.	1461
Onyx and Crystal.	60	0	0	One thousand four hundred and forty.	1440
Pharaoh's Glass.	59	5	0	One thousand four hundred and thirty-six.	1436

Section Fourth.

Instruction and Direction relative to Difference of Water-equivalents.

There is not the same assurance to be obtained in regard to these precious stones as in regard to fusible bodies. For the latter bear to be beaten, until their parts lie even, which expels the air that may have got into them in crucibles, and separates them from earthy matter. Moreover, we know not what is in the interior of stones, unless they are transparent, and can be seen through (for, in that case, whatever is within them appears), so that doubt has arisen in my mind as to the lightness of the red hyacinth, and the difference in weight between it and the dusky species. For, both the dusky and the yellow being very hard, no earthy matter, or air, or any thing else, mingles with them; which is rarely the case in respect to the red, inasmuch as most

بالتراب لا يخلو البتّة عن الهواء والياقوت الاحمر عند التقاطه لا يكون بهذا الاشراق فى اللون حتى تصفيه النار بالايقاد عليه ومهما كان فيه هواء ربى وانتفخ عند الاحماء وشقّ الجوهر للخروج ولهذا ينقبونه بالالماس حذاء كل نفاخة وطين تطريقا للهواء ان يخرج من حيث لا يضرّه ومنعا اياه عن مكافحة السطح الذى يمانعه بالعنف والشقّ ومتى لم تتخلّ تلك البطون او ضاقت عن ان يدخلها الماء عند طرحنا له فى الالة كان ما يخرج من الماء غير خالص لجسمه بل فيما بينه وبين تلك الاهوية المتخللة وكذلك الزمرذ فانه اذا انكسر شعب فيه روأبة او بدلها من غيره وامكن ان يبقى هناك مواضع خالية وعزّته تمنع عن ان ينقص بذلك ثمنه ومن الواجب على من طالع ما ذكرناه وعملنا بالماء ان لا يتشكك فى امر المياه المعروف التى تغير حالها من جهة المناقيع والمسايل والمنافع ويطرء عليها من اختلاف طبايع الفصول الاربعة فيشبهها بحال الهواء فيها لانّا لم نعتبر جميع ما اعتبرناه الا فى بقعة واحدة هى جرجانية خوارزم الموضوعة على مغيض نهر

specimens of this species have bubbles within, full of air, or, being mixed with earthy matter, are not without air on that account. Nor is the red hyacinth so splendid in color when first gathered, until fire, kindled upon it, has purified it; and, as it becomes hot, whenever there is air in the gem, it swells and is puffed up, and bursts, in order to the escape [of the air]. People, therefore, bore into this gem, by means of the diamond, opposite to every bubble or particle of dirt, to make way for the air, that it may escape without injuring the gem, and to prevent a violent and rupturing resistance to expansion. When such borings are not made, or are too small to allow of water entering into them, on our immersing the gem in the [conical] instrument, the quantity of water displaced is not precisely in accordance with the volume of the gem, but, on the contrary, is as that and the penetrated air-bubbles together determine. In like manner, when the emerald is broken, seams appear within, or, in their place, some foreign matter is found. Possibly, empty cavities always exist in this mineral. But its rarity prevents any diminution of its price on that account.

Whoever looks into our statements, and fixes his attention upon our employment of water, must be in no doubt as to well-known particulars concerning waters, which vary in their condition according to the reservoirs or streams from which they come, and their uses, and are changed in their qualities by the four seasons, so that one finds in them a likeness to the state of the air in those several seasons. We have made all our comparisons in one single corner of the earth, namely, in Jurjânîyah [a city] of Khuwârazm, situated where the river of Balkh becomes low,

نا ما دا

منه او من اى رطوبة شيئا غير الماء بل لو عملنا بعضه فى

الغلزات

من

at its outlet upon the little sea of Khuwârazm,* the water of which river is well known, of no doubtful quality; and [all our operations have been performed] early in the autumnal season of the year. The water may be such as men drink or such as beasts drink, not being fresh:† either will answer our purpose, so long as we continue to make use of one and the same sort. Or we may use any liquid whatever, though differing from water in its constitution, under the same limitation. If, on the other hand, we operate sometimes with water which is fresh and sometimes with that which is brackish, we may not neglect to balance between the conditions of the two.

This is what we wished to specify.

* This is positive testimony that, already at the commencement of the twelfth century, the Oxus no longer emptied into the Caspian, but into the little sea of Khuwârazm, that is, into the Sea of Aral. In order to contribute to a complete collection of those passages of oriental authors which relate to this interesting fact in the geographical history of our globe, I will cite a passage from Ḳazwînî's *'Ajâ'ib 'al-Makhlûḳât*, referring to the same fact in the following century. In speaking of the Jaiḥûn, this author says: ثم يمر على مدن كثيرة حتى يصل خوارزم ولا ينتفع شى من البلاد به الا خوارزم لانها تستقلّ عنه ثم ينحدر عن خوارزم وينصبّ فى بحيرة تسمى بحيرة خوارزم بينها وبين خوارزم ستة ايام "it [the Jaiḥûn] then passes by many cities, until it reaches Khuwârazm, and no region except Khuwârazm profits by it, because all others rise high out of its way; afterwards it descends from Khuwârazm and empties into a small sea, called the sea of Khuwârazm, distant three days' journey from Khuwârazm." See el-Cazwini's Kosmographie, ed. Wüștenfeld, 1r Th., 177.19

† The *Tibyân*, a commentary on the *Ḳâmûs*, thus defines the two terms شريب and شروب: الشريب الذى ليس فيه عذوبة وقد يشربه الناس على ما فيه والشروب الذى ليس فيه عذوبه ولايشربه الناس الا عند الضرورة وقد تشربه البهايم "water called *sharib* is that which is not fresh, and is drunk by men just as it is; and that called *sharûb* is water not fresh, which men do not drink except from necessity, but which is drunk by beasts."

والكهربا واعواد الاشجار المعروفة مما تجبت منها القوالب والمثل التى تصوغها
الصاغة او غيرهم فى ساير الحوالج والمقترحات اثبتناها ومياهها[h4] ووزنها فى
جدولين فليقس من الجدول مايه ومن الماء مقدار الفلز المطلوب وهاهنا[i4]
للخواطر مجال ولكل واحد فيه مقال وهو يشتمل على فصلين

الفصل الاول

فى معرفة اوزان أصول القوالب اذا كان وزن مأة مثقال اخرج عن[j4] الماء

الاسماء	مثاقيل	دوانيق	طسايج	تجنيس الطسايج	الراسب والطافى
[k4] الطين السمنجانى	ن	ب	غ	١٢٠٨	ب
الملح الصافى	مه	ج	ب	١٠٩٤	ب
السبخ	ص	ا	غ	٢١٦٤	ب
السندروس	قم	د	ب	٣٣٧٨	ط
الكهربا	قيح	غ	غ	٢٨٣٢	ط
المينا	كه	ب	ب	٦١٠	ب
القير	صو	ا	ب	٢٣١٠	ب

Chapter Third.

Observation of Other Things than Metals and Precious Stones.

We are [now] led to [consider] the proportionate weights of wax, pitch, resin, pure clay, enamel, amber, and woods of well known trees—being the materials of models and patterns formed by goldsmiths, or others practising their art—for the sake of any one who may wish to cast an equivalent weight of some metal, after the goldsmith has prepared, by his art, a pattern [of] known [material and weight]; including also the proportionate weights of other substances necessarily or optionally made use of. We have set down all these substances, with their water-equivalents, and their weights [in equivalent volumes], in two tables. Let, then, the water-equivalent be measured by the [proper] table, and by that let the proportion of metal sought for be determined.

Here may be diversity of opinion—to every one his own!

This chapter has two sections.

Section First.

Knowledge of Weights of the [Water-equivalents of] Materials of Models, when the Weight obtained out of the Water is a Hundred Mithkâls.

Names.	Mithkâls.	Dâniks.	Tassûjs.	Reduction to Tassûjs.	Floating and Sinking.[20]
Clay of Siminjân.	50	2	0	1208	s.
Pure Salt.	45	3	2	1094	
Saline Earth.	90	1	0	2164	
Sandarach.	140	4	2	3378	fl.
Amber.	118	0	0	2832	
Enamel.	25	2	2	610	
Pitch.	96	1	2	2310	

الشمع	قه	ا	غ	٢٥٢٤	ط
العاج .	سا	غ	غ	١٤٦٤	ب
الابنوس الاسود	فح	ج	غ	٢١٢٤	ب
الصدف	م	ب	غ	٩٦٨	ب
البقّم	قو	ب	غ	٢٥٥٢	ط
عود الخلاف	رمح	غ	ج	٥٩٥٥	ط

الفصل الثانى

في معرفة وزن المايعات من اناء تسع فيها من الماء الزلال الف ومايتان

الاسماء	الاوزان	الاسماء	الاوزان
الماء الزلال	١٢٠٠	الخمر	١٢٢٧
الماء الحارّ	١١٥٠	دهن السمسم	١٠٩٨
الجمد	١١٥٨	الزيت	١١٠٤
ماء البحر	١٢٤٩	حليب البقر	١٣٣٢
ماء البطيخ الهندى	١٢١٩	بيض الدجج	١٢٤٢
الماء الملح	١٣٦١	العسل	١٦٨٧
ماء القثاء	١٢٢١	دام الانسان المقصّد	١٢٤٠
ماء البطيخ المطلق	١٢٣٦	بول الناس الحارّ	١٢٢٢
خلّ الخمر	١٢٣٢	بول الناس البارد	١٢٣٠

[TABLE CONTINUED.]

Names.	Mithkâls.	Dâniks.	Tassûjs.	Reduction to Tassûjs.	Floating and Sinking.
Wax.	105	1	0	2524	fl.
Ivory.[21]	61	0	0	1464	s.
Black Ebony.	88	3	0	2124	"
Pearl-shell.	40	2	0	968	"
Bakkam-wood.	106	2	0	2552	fl.
Willow-wood.	248	0	3	5955	"

Section Second.

Knowledge of Weights of Liquids in a Vessel which holds twelve hundred [of any measure] of Sweet Water.

Names.	Weights.	Names.	Weights.
Sweet Water.	1200	Wine.	1227
Hot Water.	1150	Oil of Sesame.	1098
Ice.	1158	Olive-oil.	1104
Sea-water.	1249	Cow's Milk.	1332
Water of Indian Melon.	1219	Hen's Egg.	1242
Salt Water.	1361	Honey.	1687
Water of Cucumber.	1221	Blood of a Man in good health.	1240
Water of Common Melon.	1236	Warm Human Urine.	1222
Wine-vinegar.	1232	Cold "	1230

الباب الرابع[14]

في مقياس الماء واعتبار ذراع مكسر من الماء والفلزات ومقدار ملاء الارض
ذهبا وهو يشتمل على ثلثة فصول

الفصل الاول

في مقياس الماء لتحصيل نسب الاثقال لتقدير المساحة

امر ابو الريحان بعمل مكعب نحاس على غاية ما امكن من الصحّة وثقبه
في وجهه عند زاويتين منه على التقابل ليكون احدهما لصبّ الماء فيه
والاخر لخروج الهواء عنه ووزنه بالطيّار فارغا خاليا. ثم بماء الانهار العذب
ببلد غزنة مملوء ثلثمأة واثنين وتسعين مثقالا وسدس وثمن فاحتاج الى
مساحة ضلع المكعب وعدل الى خيط فضّة خالصة قد بلغ مدّتها الى
ان صار كل ثلثة مثاقيل اربعة عشر ذراعا من ذراع الاثواب في اسواقها
واستثنى من مقدار طول الضلع غلظ سطحي الجانبين ولوى على ما بقي
وكان ما وسعه من الملوى مأيتان وتسعة وخمسون خيطا واما الضلع فقد

Chapter Fourth.

Device for Measuring Water, Comparison between a Cubic Cubit of Water and the same of the Metals, and Quantity of Gold sufficient to fill the Earth. In Three Sections.

Section First.

Device for Measuring Water, in order to the Determination of Relations between Heavy Bodies, on Premises of Superficial Mensuration.

'Abu-r-Raihân ordered a cube of brass to be made, with as much exactness as possible, and that it should be bored on its face, at two opposite angles, with two holes, one for pouring water into it, and the other for the escape of air from it; and he weighed it in the flying balance, first empty and hollow, then filled with fresh river-water of the city of Ghaznah; [and] 392 mithkâls and $\frac{1}{6}$ and $\frac{1}{8}$ of a mithkâl [proved to be the weight of that water which it would contain]. Wanting, now, to get the superficial measure of one [inner] side of the cube, he had recourse to a thread of pure silver, so finely drawn that to every three mithkâls [of its weight] there was a length of fourteen of the cloth-cubits used in clothing-bazaars. He trimmed off from the length of a side [of the cube] the thickness of two of its opposite surfaces, and wound the thread around the remainder; and what this would hold of the thread wound around it, was 259 diameters. Now, the [length of a] side of the cube [thus shortened] would go into a cubit four times, with a remainder which would go five times into that length, leaving a [second] remainder which was one-ninth of that length. The [length of a] side

عدّ الذراع اربع مرات وبقيت بقية عدّت[m4] الضلع خمس مرات وبقيت
بقية ثانية كانت تسع الضلع فعلوم ان الضلع قد انقسم تخمسة واربعين
وان البقية الاولى النى هى فضل الذراع على الاربعة الاضلاع كانت من اجزاء
الضلع الخمسة والاربعين تسعة[n4] والبقية الثانية من الضلع من خمسة اضعاف
البقية الاولى كانت خمسة لكنها تسع الضلع فحصّة الذراع من الخيوط المذكورة
الف واثنان وثمابون وجزان من خمسة واربعين للواحد وذلك مضروب[o4] فى
خمسة واربعين مرّة فيصبير خيوط خمس واربعين ذراعا ٤٨٦٩٢[p4] ومكعب
خيوط الضلع التى هى ٢٥٩ يكون ١٧٣٧٣٩٧٩ وطسايج مايه ٩٤١٥ فقد
قلنا ان خيوط الذراع ١٠٨٢ وثلث دقايق تكون ثوالث مكعبها
٢٧٣٦٥٠١٨٠٦٩٨٤٦٧ فاذا ضربنا فى طسايج المكعب النحاسى وقسمنا المبلغ
على ثوالث هذا المكعب خرج طسايج ماء الذراع ٦٨٦٥٣٥ وقريب من
ثلث وخمس[q4] فاذا قسمناه على اربعة وعشرين ارتفعت الى المثاقيل فكانت
٢٨٦٠٥ ويبقى من الطسايج خمسة عشر[r4] وثلث وخمس وذلك وزن ماه[s4]
مكعب الذراع واجبار الكسر فيه يكون فى ثلثمأة وستّين مرّة حتى يكون

of the cube [thus shortened] was therefore understood to be divided into forty-fifth parts, of which the first remainder, the excess of a cubit above four times that length, made nine forty-fifths, and the second remainder of that length, (of which the first remainder was one-fifth,) made five forty-fifths, which is the same as one-ninth of that length. Consequently a cubit would take in $1082\frac{2}{45}$ of the mentioned diameters of the thread; which being multiplied by 45, 48,692 is produced as the [number of] diameters of the thread to forty-five cubits.

The cube of the [number of] diameters in the [shortened length of a] side, namely, 259, is 17,373,979; and the weight of water of the same volume is 9415 ṭassûjs. But we have said that the number of diameters of the thread to a cubit was [found to be] $1082\frac{3}{60}$, of which the cube is 273,650,180,698,467 [$\div 60^3 = 216{,}000$]. So then, if we multiply [this sum] by the [number of] ṭassûjs of [water contained within] the brazen cube, and divide the product by the third power of [the number of diameters of the thread held within the length of an inner side of] this cube, the quotient is the [weight in] ṭassûjs of a [cubic] cubit of water, namely, 686,535 and about $\frac{1}{3}$ and $\frac{1}{5}$ more. If we divide this weight by 24, the result is in mithkâls, of which there are 28,605, with a remainder of 15 ṭassûjs and $\frac{1}{3}$ and $\frac{1}{5}$. That is the weight of a cubic cubit of water. The fractions in this sum are consolidated [by multiplying it] into 360; which gives [the weight of] three hundred and sixty cubits cube [of water], amounting, in mithkâls, to 10,298,033.

This is what we wished to explain.[22]

مكاعيب ٣٦٠ الذراع بعدد هذه المرّة[u4] ومثاقيلها ١٠٢٩٨٠٣٣ وذلك ما اردنا بيانه

الفصل الثانى

فى معرفة عدد اوزان الذراع المكسر من كل فلز

وعند حصول هذا الاصل يعود الى اصل اخر وهو تفاضل ما بين الاثقال المتساوية الجثث المختلفة الاجناس بقوة النسب التى بين الفلزات فى الحجم قد ذكرنا فى الباب الاول من هذه المقالة انه يصير ما نسبة الاثقال المتساوية فى الوزن من المياه معلوما وتكون نسبة وزن الماء الاقلّ الى وزن الماء الاكثر كنسبة وزن ذى الماء الاكثر الى وزن ذى الماء الاقل فان نسبة التكافى لازم بين اوزان الاثقال وبين انواع مسايح اجسامها وامتدادها وهى موضوعة وهناك اصل ثان ونقول اذا كان وزن مثاقيل ماء مكعب الذراع المكسر ٢٨٦٠٥ يتبعها خمسة عشر طسوجا وثلث وخمس وكان كل مأة واثنين وثمانين مثقالا منّا بمنّ مأيتين[u4] وستّين درهما كانت امناء الذراع المكسر من الماء مأة وسبعة وخمسين منّا وستّة اساتير ونصف وربع وخمس[v4] ومعلوم ان قدر وزن الذراع الواحد المكسر من اى فلز كان عند وزن مايه[w4] كالفلز[x4]

Section Second.

Knowledge of Numbers for the Weights of the measured Cubit of all Metals.

The principle last considered having been made out, we turn to another, which is a difference [in weight] between heavy bodies of like masses, but differing in kind, by virtue of relations subsisting between metals in respect to volumes. We have already stated, in the first chapter of this lecture, that whatever may be the relation between heavy bodies alike [in volume], as to [absolute] weight, is known from their water-equivalents; and that the relation of the weight of the less water-equivalent to the weight of the greater water-equivalent is as the relation of the weight of that body of which the greater quantity of water is the equivalent to the weight of that body of which the less quantity of water is the equivalent. Consequently there must be an inverse relation between the [absolute] weights of heavy bodies and the dimensions in length, breadth, and height, of those water-equivalents put down.

Now for a second principle. Since the weight of a volume of water equivalent to the cube of the measured cubit is 28,605 mithkâls, together with 15 tassûjs and $\frac{1}{3}$ and $\frac{1}{5}$, and since 182 mithkâls make a mann (one mann being computed at 260 dirhams), [a cube of] the measured cubit of water weighs 157 manns, 6 'istârs and $\frac{1}{2}$ and $\frac{1}{4}$ and $\frac{1}{5}$. It is also known that the weight of the [cube of the] measured cubit of any metal what-

٢٤٠٠ طسوج[y4] من ذلك عند طسايج[z4] مايّه[a5] الموضوعة بحذايه فى الجدول واول هذه المقادير مجهول ومضروب ثانيها فى ثالثها اعنى مضروب وزن ماء الذراع الواحد فى ٢٤٠٠ وذلك بالطسايج ٦٨٦٥٣٥[b5] فمتى قسم هذا العدد على كل واحد من مياه تلك الفلزات خرجت طسايج ذراع[c5] ذلك الفلز وليس بضاير ان نضع بازاء كل فلز مثاقيل وزن الذراع المكسر منه بطسايجها وكسور الطسايج وكم يكون من امناء واساتير[d5] فى جدول وهو هذا

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اسماء الفلزات	مثاقيل	طسايج	كسورها	امناء	اساتير	كسورها
الذهب	٥٤٤٨٦٩	يا	تسع	٢٩٩٣	لا	ثلث وخمس
الزيبق	٣٨٧٨٧٣	د	ربع	٢١٣١	و	نصف وثلث
الاسرف	٣٢٣٨٣٧	يب	ربع	١٧٧٩	يد	
الفضة	٢٩٤٦٥٠	ى	ثلث وخمس	١٦١٨	لح	ثلث
النحاس	٢٤٧٨٤٦	يح	خمس	١٣٦١	لا	نصف وثلث
الشبه	٢٤٥١٩١	و	خمس	١٣٤٧	ح	خمس
الحديد	٢٢١٤٦٣	ا	ثلث وخمس	١٢١٦	لج	خمس
الرصاص	٢٠٩٣٠٩	يد	ثلثان	١١٥٠	ب	خمس

ever is to the weight of its equivalent of water as 2400 ṭassûjs of that metal to the [weight in] ṭassûjs of its water-equivalent, put down opposite to it in the table [above given]. The first of these proportionals being unknown, if the second is multiplied into the third—I mean, the weight of a volume of water equivalent to [the cube of] one cubit, which is, in ṭassûjs, 686,535, being multiplied by 2400—and if this [product-] number is divided by the [weight of the] water-equivalent of each of those metals, the quotient is the weight in ṭassûjs of a [cubic] cubit of that metal.

It will do no harm to put down, opposite to each metal, the weight of [a cube of] the measured cubit thereof, in mithḳâls, ṭassûjs, and fractions of ṭassûjs, and the number of manns and 'istârs which that amounts to, in a table, as follows:

Numbers for the Weights of the measured Cubit of all Metals.[23]

Names of Metals.	Mithḳâls.	Ṭassûjs.	Fractions.	Manns.	'Istârs.	Fractions.
Gold.	544,869	11	$\frac{1}{9}$	2993	31	$\frac{1}{3}+\frac{1}{5}$
Mercury.	387,873	4	$\frac{1}{4}$	2131	6	$\frac{1}{2}+\frac{1}{3}$
Lead.	323,837	12	$\frac{1}{4}$	1779	14	
Silver.	294,650	10	$\frac{1}{3}+\frac{1}{5}$	1618	38	$\frac{1}{3}$
Copper.	247,846	18	$\frac{1}{5}$	1361	31	$\frac{1}{2}+\frac{1}{3}$
Brass.	245,191	6	$\frac{1}{5}$	1347	8	$\frac{1}{5}$
Iron.	221,463	1	$\frac{1}{3}+\frac{1}{5}$	1216	33	$\frac{1}{5}$
Tin.	209,309	14	$\frac{2}{3}$	1150	2	$\frac{1}{5}$

This exhausts all the more interesting matter which admits of being extracted from the work now under analysis. In the section following the last translated, our author sets himself to calculate the quantity of gold which would compose a sphere equal to the globe of the earth. He prescribes to himself this task almost as a matter of religious obligation, in order to find the ransom which, according to the Ḳurân, the infidels would offer to God in vain for the pardon of their sins; for he begins with citing the eighty-fifth verse of the third chapter of the Ḳurân, which reads: "truly there will not be accepted as ransom from those who were infidels and died infidels as much gold as would fill the earth; for them there are severe pains; they shall have no defender." We will not follow the author in his laborious calculations, but will content ourselves with merely noting some of his results. He says that the cubit of the bazaar at Baghdâd is twenty-four fingers long, each finger being of the thickness of six grains of barley placed side by side. The mile contains four thousand cubits, and three miles make a farsang. The circumference of the earth is 20,400 miles, and its diameter is $6493\frac{138}{277}$ miles. Finally, the number of mithḳâls of gold capable of filling the volume of the globe is, according to him:

36,124,613,111,228,181,021,713,101,810.

For the purpose of comparing these numbers with ours, I will observe that the radius of a sphere equal in volume to the spheroid of the earth is 6,370,284 metres; this would give us one mile $=1962.048$ m., and one cubit $=490.512$ millimetres: that is to say, if these measures admitted of a rigorous comparison; but Laplace has very justly observed* that the errors of which the geodetical operations of the Arabs were susceptible do not allow us to determine the length of the measure which they made use of, for this advantage can only be the result of the precision of modern operations. I have endeavored to measure the thickness of six grains of barley placed side by side, and in sixty trials I have obtained as maximum thickness 17.3 mm., as minimum 13 mm., the average of the sixty determinations being 15.31 mm.; which would give us for the length of the cubit 367.44 mm., a result evidently inexact, by reason of the want of delicacy of the standard by which the valuation was made. We shall return to this subject later, and shall attempt to find a more probable result, such as will show which of the two values is nearer the truth.

In the fifth and last chapter of our author's third lecture, he takes up the problem of the chess-board, of which he supposes the squares to be filled with dirhams, each square containing twice the number in the preceding. He begins with finding the

* **Exposition du Système du Monde, p. 395, 6me édition, 1835.**

total number of dirhams to be 18,446,744,073,709,551,615, expressed by him in *abujad* signs thus: هاواهطغزجرغددزوددحا. Then he applies himself to find the dimensions of the treasury in which this treasure should be deposited, and finally cites the verses of the poet 'Anṣarî, chief of the poets of the Sulṭân Maḥmûd of Ghaznah, which fix the time in which one might spend this sum at 200,000,000,000,000,000 years. The verses are as follows:

شاها هزار سال بملك اندرون بزی ∴ زان پس هزار سال بناز ابدرون ببال
سالی هزار ماه و ماهی صد هزار روز ∴ روزی هزار ساعت و ساعت هزار سال

"O king! live a thousand years in power; after that, flourish a thousand years in pleasure: be each year a thousand months, and each month a hundred thousand days, each day a thousand hours, and each hour a thousand years."

Before giving a succinct description of the physical instruments described and mentioned in the Book of the Balance of Wisdom, I think it well to pause and review the results arrived at by the Arab physicists, and recorded by our author in the first part of his work. I will begin by attempting to give a little more precision than has been done hitherto to the units of measure, as the cubit and the mithḳâl.

We have seen that the cubic cubit of water weighed by 'Abu-r-Raiḥân at Ghaznah weighed 28,605.647 mithḳâls. The elevation of Ghaznah, according to Vigne, is 7000 English feet, or about 2134 metres, which would correspond to a medium barometric pressure of 582 millimetres. The temperature of the water made use of by 'Abu-r-Raiḥân in this experiment is not known to us; but not only have we seen our author state in the clearest manner that he was aware that temperature had an influence upon the density of liquids; we may also see, upon comparing the specific gravities of liquids obtained by the Arabs with those obtained by modern physicists, that their difference between the density of cold and of hot water was .041667, while, according to the experiments of Hällström (see Dove's Repert. d. Physik, i. 144–145), the difference between the densities of water at 3°.9 and at 100° (Centigrade) is .04044. We can assume, then, with great probability, that a physicist so experienced as 'Abu-r-Raiḥân would not have taken water at its maximum summer-heat, but that he would have made his experiments either in the autumn, as our author advises, or in the spring. The temperature of the rivers in those regions in autumn has not, to my knowledge, been directly determined by any one, but the temperature of the Indus, at 24° N. lat., in February, 1838, was measured by Sir A. Burnes (see Burnes' Cabool, p. 307), and was found to be, on an average, 64° 2 Fahrenheit, which is

equivalent to 17°.89 Centigrade; and we may, as it seems to me, with sufficient probability, admit that the water used by 'Abu-r-Raiḥân was of a temperature about 62° Fahrenheit, and that its density, according to Hällström, was .999019, considered in reference to water at the zero Centigrade, and .998901, considered in reference to water at its maximum density. Now we know that a cubic metre of distilled water, at 4° C., weighed at Paris in a vacuum, weighs 1,000,000 grammes; if, then, we know the value of the mithḳâl in grammes, we shall be able to compare the metre and the cubit.

According to the Ḳâmûs, the mithḳâl is 1$\frac{3}{7}$ dirhams, the dirham 6 dâniḳs, the dâniḳ 2 ḳîrâṭs, the ḳîrâṭ 2 ṭassûjs; our author, however, makes use of a much less complicated mithḳâl, which is composed of 24 ṭassûjs; if, then, these ṭassûjs are the same as those of the Ḳâmûs, his mithḳâl is equivalent to the dirham of the latter. I shall not follow the methods pointed out by Oriental authors for determining the weight of the mithḳâl, for they are all founded upon the weight of different grains, no notice whatever being taken of the hygrometric condition of such grains; but I shall pursue an independent method. I would remark, in advance, that almost nowhere, not even at Baghdâd, has the Arab dominion of the first times of the Khalîfs left so profound traces as in the Caucasus, where, as in Daghistân, for instance, while no one speaks Arabic, correspondence is carried on exclusively in that language. Now I have made, by order of the Government, and conjointly with M. Moritz, Director of the meteorological observatory at Tiflîs, a comparison of the weights and measures used in the different provinces of Transcaucasia, and have found the value of the mithḳâl in grammes to be as follows:

In the district of Kutais,	4.776	grammes.	Georgia.
" Thelawi,	4.227	"	
" Sighnakh,	4.226	"	
" Nakhjiwân,	4.590	"	"Muslim" Provinces.
" Ordubad,	4.499	"	
" Shemakhi,	4.305	"	
In the city of Shemakhi,	4.704	"	
" " (another),	4.572	"	
" " "	4.621	"	
In the district of Baku,	4.175	"	
" " "	4.660	"	
" Karabâgh,	4.610	"	
" Sheki,	4.496	"	
" " canton Eresh,	4.272	"	
" " " " (another),	4.426	"	
" " " Khajmasi,	4.869	"	
" Lenkorân,	4.660	"	
" Derbend,	4.538	"	Daghistân.
" Samur,	4.792	"	
Average of nineteen values,	4.527	grammes.	

Hence it is seen that the particular values vary in either direction from this average, to as much as $+0.342$ gr. and -0.352 gr., and I accordingly believe that the value of the mithḳâl may be taken at 4.5 gr. without fear of any considerable error.

Accepting, then, $4\frac{1}{2}$ grammes as the equivalent of a mithḳâl, we shall find that the weight of a cubit cube, 28,605.647 mithḳâls, is 128,725.41 grammes. In order to compare with this the weight of a cubic metre of water, it will be necessary to reduce the latter to the conditions of Ghaznah with respect to temperature, atmospheric pressure, and intensity of the force of gravity. Calling m^3 the weight of the cubic metre of water, and considering only the temperature of the water of 'Abu-r-Raiḥân, we shall find $m^3 = 998{,}901$ gr., which would be the weight of a cubic metre of water in Paris at 16°.67 C. in a vacuum. Now, according to the experiments of M. Regnault, a litre of dry air in Paris, at zero of temperature, and under a barometric pressure of 760 mm., weighs 1.293187 gr.; a metre, then, will weigh, under the same conditions, 1293.187 gr. The intensity of gravity at Paris, g, is 9.80895 m.; and at Ghaznah, g', 9.78951 m.; then d', the weight of a cubic metre of dry air at Ghaznah, will equal 931.241 gr.* As we have no means of ascertaining the hygrometric condition of the atmosphere during the experiment of 'Abu-r-Raiḥân, we are compelled to treat it as if perfectly dry: by deducting, then, d' from m^3, we shall render this latter number in all respects comparable with c^3, and we shall have $\frac{c^3}{m^3} = 0.1291$, and $\frac{c}{m} = 0.505408$: c, then, equals 505.408 mm., a value which differs from that which we obtained by comparing the Arab measurement of a degree with our own, by 14.896 mm., that is to say, by about the average thickness of six grains of barley laid side by side; and I think we may assume, without danger of too great an error, $c = 500$ mm. Notwithstanding the hypotheses which I have been compelled to introduce into this calculation in order to render it practicable, the result obtained by it seems to me preferable to that derived from a comparison of the dimensions of the earth, for here we can at least form an approximate idea of the amount of possible error, while in the other case we are deprived of all power of applying a test, by our ignorance respecting the degree of precision of the geodetic instruments of the Arabs.[24]

This furnishes us the means of ascertaining the fineness of the

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* The accelerating force of gravity is here calculated by the formulas $g' = g\,(1 - 0{,}002588 \cos. 2l)\left(1 - \frac{2z}{r}\right)$, and $r = 20{,}887{,}538\,(1 + 0{,}001644 \cos. 2l)$; where $l = 34°$, and $z = 7000$ Eng. ft.; and by the formula $d' = d\,\frac{g'h'}{gh}\left(\frac{3000 + 11t}{3000 + 11t'}\right)$, where t is the temperature in degrees of Centigrade.

silver wire by which 'Abu-r-Raiḥân measured the side of his cube, for $w = \frac{45c}{48690}$, or .000924*c*, or .462 mm. This *ne plus ultra* of the skill of the Arab jewellers will seem to us coarse enough, compared with the silver threads obtained by the ingenious process of Wollaston, of which the diameter is only .0008 mm., or $\frac{1}{30000}$ of an English inch. But it should not be forgotten that it is not long since .006 mm. was regarded as the limit of the ductility of gold thread, and that accordingly, considering the imperfect mechanical means which the Arabs had at their disposal, a metallic wire of a thickness less than half a millimetre was in fact something remarkable.

On examining the determinations by the Arabs of specific gravities, we see that they had weighed, in all, fifty substances, of which nine were metals, ten precious stones, thirteen materials of which models were made, and eighteen liquids. The smallness of the list ought not to surprise us, for most of the substances which figure in our modern lists of specific gravities were entirely unknown to the Arabs. What is much more surprising is the exactness of the results which they obtained; for the coarseness of their means of graduating their instruments, and the imperfection at that time of the art of glass-making, rendered incomparably more difficult then than now this kind of investigation, which, in spite of the immense progress of the mechanical arts, is still regarded as one of the most delicate operations in physical science. It is very remarkable that the Muslim physicists, who had detected the influence of heat on the density of substances, did not notice its effect upon their volume: at least, the dilatation of bodies by heat is nowhere mentioned by our author; and this circumstance, together with their ignorance of the differences of atmospheric pressure, introduces a certain degree of vagueness into the values which they give for specific gravities. In comparing, as I have done in the following table, our author's valuation of specific gravities with that obtained by modern science, I shall regard the former as having reference to water at the freezing point, and under a pressure of 760 mm., both as not knowing what else to do, and as supported by these two considerations: first, that we have already noticed the slight difference between the densities given by our author for cold and hot water, and that which is true of water at the freezing and boiling points;* secondly, that our author, according to his own statement, made the greater part of his determinations at Jurjânîyah, which, in my opinion, is no other than the modern Kuna-Ûrghenj, a city situated about four geographical miles from the point where the Oxus empties into the Sea of Aral, where he was able to raise the temperature of water to 100° C., and

* See p. 80.

which consequently must be at the level of the sea. The modern values of the specific gravities are given, for the most part, and when not otherwise noted, from Schubarth's Sammlung physikalischer Tabellen (Berlin: 1849); a few are taken from the Annuaire du Bureau des Longitudes, Paris, for 1853 (marked "Ann."), from Schumacher's Jahrbuch for 1840 ("S."), from Brande's Encyclopedia ("Br."), from Hällström, as cited above ("H."), and from Gmelin's Chemistry ("G."). The substances are arranged in the same order as they have been given in our author's tables.

Substances.	Specific Gravities: acc. to 'al-Khâzinî.		Specific Gravities: acc. to modern authorities.	
Gold,	19.05	cast,	19.258–19.3	
Mercury,	13.56		13.557	
Lead,	11.32		11.389–11.445	
Silver,	10.30		10.428–10.474	
Bronze,				Ann. “
Copper,	8.66	cast,	8.667–8.726	8.85 Ann.; 8.897 S.
Brass,	8.57		8.448–8.605	
Iron,	7.74	forged,	7.6–7.79	
Tin,	7.32	English cast,	7.291	
Celestial Hyacinth,	3.96	Oriental Sapphire,	4.83	
Red Hyacinth,	3.85	" Ruby,	3.99;	4.28 Ann., S.
Ruby of Badakhshân,	3.58			
Emerald,	2.75		2.678–2.775	
Lapis Lazuli,	2.69		2.055;	2.9 Ann.
Fine Pearl,	2.60		2.684	2.75 Ann.; 2.617 S.
Cornelian,	2.56		2.62	
Coral,	2.56		2.69	
Onyx and Crystal,	2.50	Onyx, / Mountain-crystal,	2.628–2.817 / 2.686–2.88	
Pharaoh's Glass,	2.49	English mirror-glass, / " flint- "	2.45 / 3.442	
Clay of Siminjân,	1.99	Clay,	1.068–2.63	
Pure Salt,	2.19		2.068–2.17	
Saline Earth,	1.11			
Sandarach,	.71		1.05–1.09	
Amber,	.85		1.065–1.085	
Enamel,	3.93			
Pitch,	1.04	white,	1.072	
Wax,	.95	yellow,	.965	
Ivory,	1.64		1.825–1.917	
Black Ebony,	1.13		1.18	
Pearl-shell,	2.48	Shell of Mactra podolica, of the Caspian Sea,	2.647*	
Bakkam-wood,	.94	Brazil-wood,	1.031	
Willow-wood,	.40		.585	
Sweet Water,	1.		1.	
Hot Water,	.958	boiling,	.9597 H.	
Ice,	.965		.916–.9267	
Sea-water,	1.041		1.0286;	1.04 S.

Substances.	Specific Gravities: acc. to 'al-Khâzinî.		acc. to modern authorities.
Water of Indian Melon,	1.016		
Salt Water,	1.134	saturated solution,	1.205 G.
Water of Cucumber,	1.017		
Water of Common Melon,	1.030		
Wine-vinegar,	1.027	Vinegar,	1.013–1.080 Br.
Wine,	1.022	various kinds,	.992–1.038
Oil of Sesame,	.915		
Olive-oil,	.920		.9176–.9192
Cow's Milk,	1.110		1.02–1.041
Hen's Egg,	1.035		1.09
Honey,	1.406		1·450
Blood of a Man in good health,	1.033		1.053 Br.
Warm Human Urine,	1.018	*	1.011
Cold " "	1.025		

This table shows us that the Arabs conceived much earlier than we the idea of drawing up tables of specific gravities, for the first European tables of this character are, according to Liber (Hist. Philos. des Progrès de la Physique, iv. 113–114), due to Brisson, who died in 1806. The first person in Europe to occupy himself with determining the specific gravity of liquids was Athanasius Kircher, who lived 1602–1680: he attempted to attain his purpose by means of the laws of the refraction of light. After him, the same subject drew the attention of Galileo, Mersennes, Riccioli, the Academicians of Florence, assembled as a learned body in 1657, and finally of the celebrated Boyle, born 1627. The latter determined the specific gravity of mercury by two different methods: the first gave as its result $13\frac{92}{121}$, or 13.76, the other $13\frac{10}{28}$, or 13.357; both are less exact than the value found by the Arab physicists of the twelfth century.

I will conclude this analysis by a brief description of the different kinds of balance mentioned in this work; I shall cite the text itself but rarely, and only when it contains something worthy of special notice.

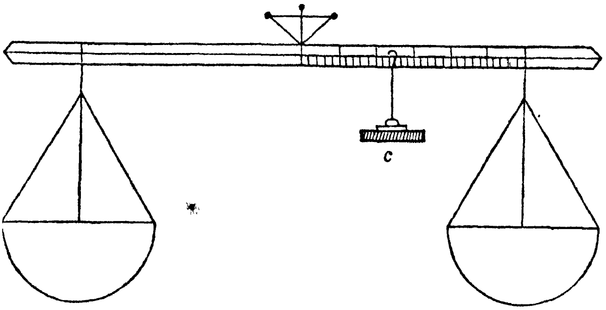
Our author first describes a balance which he calls Balance of Archimedes, and professes to quote the details respecting its use word for word from Menelaus: هذا حكاية الفاظ الرجل حرفا حرفا, without, however, giving the title of the latter's work.

In order to ascertain the relation between the weight of gold and that of silver, Archimedes took, according to our author, two pieces of the two metals which were of equal weight in air, then immersed the scales in water, and produced an equilibrium between them by means of the movable weight: the distance of this weight from the centre of the beam gave him the number required. To find the quantity of gold and of silver contained in an alloy of these two metals, he determined the specific gravity of the alloy, by weighing it first in air and then in water, and compared these two weights with the specific gravities of

This is the figure of the Balance of Archimedes given in my manuscript:[25]

صورة ميزان ارشميدس

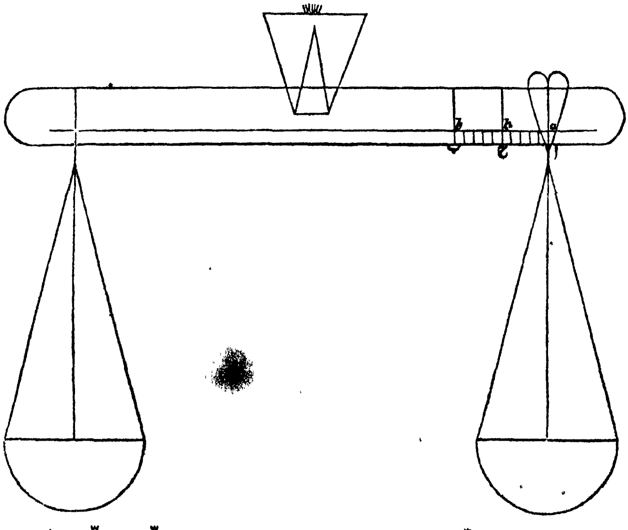
Figure of the Balance of Archimedes.



a. كفّة الذهب c. المنقّلة b. كفّة الفضّة

Bowl for Gold. Movable Weight. Bowl for Silver.

Another balance described by our author is that of Muḥammad Bin Zakarîyâ of Rai. It is distinguished from that of Archimedes by the introduction of the needle, called by the Arabs اللسان, "the tongue," and by the substitution of a movable suspended scale for the movable weight. The following is an exact copy of the figure representing it:[26]



c. كفّة الفضّة ثابتة d. كفّة الذهب وهي المنقلة

Bowl for Silver, fixed. Bowl for Gold, movable.

A note inserted in my manuscript between the two bowls, which I have copied and translated below, explains the mode of using this balance.

اذا كان الجرم المشكوك فيه فضّة خالصة فيعتدل كفّتها على آ طرف العمود
ومبدء الحساب واذا كان ذهبا ابريزا فتقرب من اللسان عند بَ غاية القرب
واما اذا كان ممتزجا فتقف عند حَ ما بين آ بَ ويكون نسبة ما فيه من
الذهب الى ما فيه من الفضة كنسبة اجزاء احَ الى اجزاء احبَ فيحفظ
هذا فيه

When the body in question is pure silver, the bowl containing it will be balanced at *a*, which is the extremity of the beam, and the place where the scale commences. When it is the purest gold, the bowl will come as near to the tongue as possible, at *b*. When it is mixed, it will stop at *ḥ*, between *a* and *b*; and the relation of the gold in the body to what it contains of silver will be as the relation of the parts [of the scale] *a ḥ* to the parts *a ḥ b*. Let this, then, be kept in mind with regard to the matter.

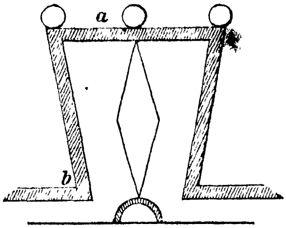
A third balance described by our author is that of 'Abû-Ḥafṣ 'Umar Bin 'Ibrâhîm 'al-Khaiyâmî. I do not copy the figure of it, because it is in every respect similar to the balance of Archimedes, excepting the movable weight. Its application is very simple. A piece of gold is weighed in air, and then in water; the same thing is done with a piece of silver; and a piece of metal about which one is doubtful whether it is pure gold, or silver, or contains both metals at once, is also tried; and the comparison of specific gravities thus obtained serves to settle the question.

Finally, in the fifth lecture, he gives a very minute description of the balance of wisdom, according to 'Abû-Ḥâtim 'al-Muẓaffar Bin 'Isma'îl of 'Isfazâr. He begins by remarking that, the balance being an instrument for precision, like astronomical instruments, such as the astrolabe and the zîj 'aṣ-ṣafâ'iḥ,[27] its whole workmanship should be carefully attended to. He next describes the beam, العمود, the front-piece, العريضة, the two cheeks, ا, between which the tongue moves, and the tongue itself, As regards the beam, he advises that it be as long as it may, "because length influences the sensibility of the instrument;" and indicates a length of four bazaar-cubits, or two metres, as sufficient. He gives to his beam the form of a parallelopiped, and marks upon its length a division into parts, two of which must be equivalent to its breadth. It must be of iron or bronze. The tongue has the form of a two-edged blade, one cubit in length; but he observes, as in regard to the beam,

that the longer it is the more sensitive will be the instrument. He directs to fasten it to the beam by two screws, after having carefully determined the centre of gravity of the beam, by placing it, experimentally, across the edge of a knife; and to fit it with nicety, so that the centre of gravity may be as little displaced as possible. We do not stop to give the description of the tongue and its frame, and limit ourselves to copying exactly the accompanying figure, which represents these parts of the balance:[18]

a. العريضة
Front-piece.

b. المعقف
Bending-place.



After this, our author exhibits the general principles which concern the suspension of the beam of the balance. The passage deserves to be transcribed and literally translated, as is done below.

الفصل الرابع

فى العلم الكلى المطلق فى احكام المحور والمثقب والمثقل

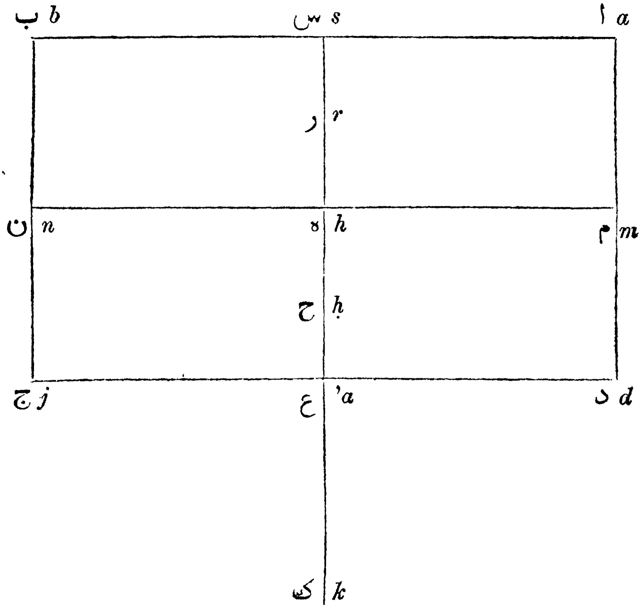
اذا كان العمود اسطوانى الشكل سانجا عن اللسان فالمحور يقع عليه من ثلاثة وجوه احدها محور الاعتدال وهو ان يكون على مركز ثقله فى وسطه الحقيقى قايما على طوله فيكون العمود سلس المدار مطواعا للوزن ان يقف حيث يهمله فى دورانه ولا يوازى الافق طبعا لان السهم الخارج من مركز العالم الى مركز ثقله يقسمه بالقطع بنصفين متساويين حيث وقف

Section Fourth. [Lect. 5, Chap. 2.]

Scientific Principles of a General Nature, universally applicable, relative to Determination of the Axis, the Place of Perforation [for it], and the Point of [its] Support [to the Beam].

The beam being columnar in shape, detached from the tongue, there are three varieties of axis: 1, the axis of equipoise, at the centre of gravity of the beam, exactly in the middle of it, and perpendicular to its length; so that the beam readily gyrates in obedience to equiponderance [in its two equal arms], stopping, in its going round, wherever that [moving force] ceases to act, and not becoming, of itself, parallel with the horizon; because a right line drawn from the centre of the world to its centre of

والثانى محور الانقلاب وهو ان يقع فيما بين مركزى العالم وثقل العمود فانه اذا حرّك انقلب معكوسا بالطبع لان السهم الخارج من مركز العالم يقسمه بقسمين مختلفين والمايل ارجح فينقلب لأجله والثالث محور الالتزام وهو ان يقع المحور فوق مركز ثقله فاذا تحرّك يقسمه السهم الخارج من مركز العالم الى مركز علقه[f5] بقسمين مختلفين ويكون الشايل منه ارجح عظم فيرجّح ويرجع فيقف على محاذاة الأفق لان السهم هاهنا يقسمه بنصفين



gravity cuts it into like halves wherever it stops; 2, the axis of reversion, between the centre of the world and the centre of gravity of the beam, so that, when the beam is put in motion, it turns, of itself, upside down, because a right line drawn from the centre of the world [through the axis, when the centre of gravity is thrown out of that line] divides it into two parts differing one from the other, of which the one going downward preponderates, and the beam is consequently reversed; 3, the axis of [parallelism by] necessary consequence, above the centre of gravity of the beam, so that, when the beam is put in motion, a right line drawn from the centre of the world to its centre of suspension divides it into two parts differing one from the other, of which the one going upward exceeds in mass, and consequently preponderates and returns, and so the beam stops in a horizontal position; because, in this case, a right line [drawn from the centre of the world to the point of suspension] divides it

متساويين فيلزم الموازاة لذلك يكن العمود السائج ابجد ومن ينصفه طولا وسع ينصفه عرضا ونقطة ه ملتقى الخطّين مركز ثقل العمود فاذا جعلناه محورا مطاوعا يقف حيث يهمل لان سهك السهم الذى يخرج من ك مركز العالم الى ه مركز الثقل يقسم سطح ابجد بقسمين متساويين بشرح يطول ذكره هذا اذا مال الى جهة واذا جعلنا فوق ه عن مركز الثقل[g5] الى جهة فخطّ كرس يقسم السطح بقسمين مختلفين ويكون الشايل اعظم فيرجح ويرجع فيلزم موازاة[h5] الافق واذا جعلنا ح تحت ه عن مركز الثقل ومال الى جهة فيكون المايل ارجح لان السهم يقسم ابجد بقسمين مختلفين والنقطة المايلة تكون ارجح فينقلب من فوق الى تحت وهذا هو حكم السائج منه واما اذا انضمّ الى ثقله ثقل اللسان القايم عليه فى وسطه فانه يختلف مركز ثقله عن السائج ويلزمه مركز ثقل

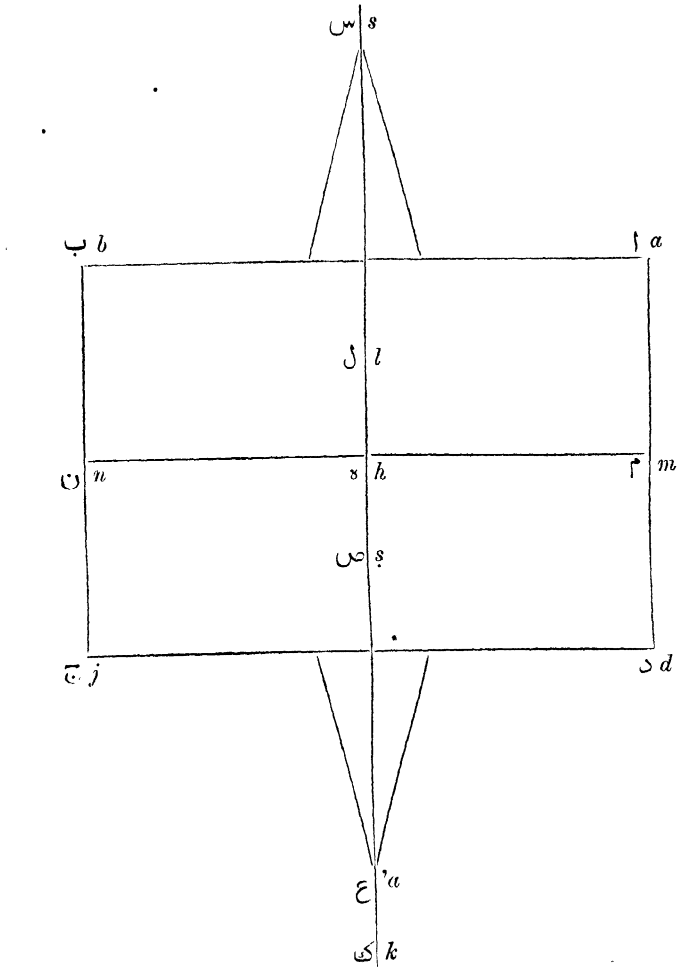
into two like halves, and parallelism with the horizon is a necessary consequence.

Let $abjd$[29] be a detached beam, let the line mn divide it into halves, lengthwise, and the line $s'a$ halve it across, and let h, the point where the two lines meet, be the centre of gravity of the beam. When, therefore, we set the beam on an axis [at that point], so that it obeys [the equal weights of its two arms], it stops wherever it is left to itself; because the right line shk, drawn from k, the centre of the world, to h, the centre of gravity, divides the plane $abjd$ into like halves, according to an explanation which it would take long to state. This equal division occurs, however the beam may incline. When we set [the beam on an axis at r,] above h, away from the centre of gravity, then the line krs [drawn from the centre of the world to the point of suspension] divides the plane into two parts differing one from the other, of which the one going upward has the greater bulk, so that it preponderates and returns, and parallelism with the horizon is a necessary consequence. When we set the beam on an axis at h, below h, away from the centre of gravity, and the beam leans, then that part of it which goes downward preponderates; because the right line [drawn from the centre of the world to the point of suspension] divides $abjd$ into two parts differing one from the other, and the mass[30] going downward preponderates, so that the beam turns itself upside down.

So much for the beam when detached from the tongue.

In case of the combination of its own gravity with the gravity of the tongue, placed at right angles to it, in the middle of it, the common centre of gravity differs from that of the detached beam, and must necessarily be another point; and that other point corresponds to the centre of equipoise in the detached beam, so that, when the beam is set upon an axis [at that point], it stops wherever it is left to itself.

آخر وذلك الاخر حكمه حكم مركز الاعتدال فى السانج فانه اذا جعل محورا
يقف حيث يهمل واللسان يفرض اما من فوق نحو س ونقطة ل مركز ثقله



واذا جعل محورا يكون محور الاعتدال فكل نقطة فرضت فوق ل فهو
محور الالتزام لان السهم الخارج اليها يقسم السطح بقسمين والشايل

The tongue may be made fast above [the beam], in the direction of *s*, the point *l* becoming the common centre of gravity; and an axis at this point is the axis of equipoise. So that the axis of [parallelism by] necessary consequence is at any point fixed upon above *l*, because a

يكون ارجح فيرجع ويقف على موازاة الافق وكل نقطة فرضت تحت ل
فهو محور الانقلاب فاذا مال يكون القسم المايل منه اعظم فيميل الى ان
ينقلب معكوسا واذا فرض اللسان تحت العمود نحو ع فيكون مركز ثقله
نقطة ص فهو محور الاعتدال فاذا حرّك يقف حيث يهمل فاذا جعل المحور
فوق ص فيصير محور الالتزام فيرجع الشايل ويقف على محاذاة الافق واذا
جعل تحت ص فيصير محور الانقلاب ولانّه الاختلاف يقع من وجوه آ من
جهة كونه ساذجا ومركبا مع اللسان مستويا ومقلوبا ب ويقع من جهة
المحور على مركز ثقله او فوقه او تحته ج ويقع من موضع معلاق الكفّتين
منه على محاذاة المحور او فوقه او تحته فهذه سبعة وعشرون[15] وقوعا وما يلزم
لكل وضع منها وقد اثبتنا لهذه الوقوعات الجدول

right line drawn to that [higher point, from the centre of the world] divides the plane [*abjd*] into two parts, of which the one going upward preponderates, so that it returns, and stops in a horizontal position; and [an axis] at any point fixed upon below *l* is the axis of reversion, so that, when the beam inclines, that part of it which goes downward has the greater bulk, and consequently tips until it turns upside down.

Should the tongue be made fast below the beam, in the direction of *'a*, and so the common centre of gravity become the point *ṣ*, then [an axis at this point] is the axis of equipoise, and, therefore, when the beam is put in motion, it stops wherever it is left to itself. But, when the axis is put above *ṣ*, it becomes the axis of [parallelism by] necessary consequence, so that the part [of the beam] which goes upward returns, and stops in a horizontal position. When the axis is put below *ṣ*, it becomes the axis of reversion.

Inasmuch as there is change [in the adjustment of the balance] in several ways: 1, in respect to the beam's being either detached or joined to the tongue—[the tongue] standing up or reversed [according as it is made fast above or below the beam]; 2, in respect to the [position of the] axis [in each of the cases supposed with reference to the connection of the beam] either at, or above, or below, the centre of gravity; 3, in respect to the place on the beam of the means of suspension of the two bowls, either even with, or above, or below, the axis—twenty-seven incidents [constituting changes of adjustment] are made out, together with a result [as regards the action of the balance] dependent upon each particular adjustment, and we have drawn up for these incidents the following table:

جدول اختلاف وقوع الميزان

العمود	اختلاف الوقوع اذا كان موضع ثقل معلاق كفتي الميزان	على العمود	فوق العمود	تحت العمود
حكم السانج منه المعرى عن اللسان	على مركز الثقل	اعتدال	انقلاب	التزام
	فوق المركز	التزام	انقلاب اعتدال | التزام	التزام
	تحت المركز	انقلاب	انقلاب	انقلاب اعتدال | التزام
حكم المركب منه على اللسان من فوق مستوياً[15]	على مركز الثقل	اعتدال	انقلاب	التزام
	فوق المركز	التزام	انقلاب اعتدال | التزام	التزام
	تحت المركز	انقلاب	انقلاب	انقلاب اعتدال | التزام
حكم المركب منه على اللسان من تحت مقلوباً[15]	على مركز الثقل	اعتدال	انقلاب	التزام
	فوق المركز	التزام	انقلاب اعتدال | التزام	التزام
	تحت المركز	انقلاب	انقلاب	انقلاب اعتدال | التزام

Table of Variety of Incident pertaining to the Balance.[31]

The Beam.	Determination relative to the Detached Beam, separate from the Tongue, [the Axis being]			Determination relative to the Beam connected with the Tongue, [with the Tongue fastened] above [the Beam]—standing up, [the Axis being]			Determination relative to the Beam connected with the Tongue, [with the Tongue fastened] below [the Beam]—reversed, [the Axis being]		
Variety of Incident, according as the Means of Suspension of the two Bowls of the Balance is	at the Centre of Gravity.	above the Centre.	below the Centre.	at the Centre of Gravity.	above the Centre.	below the Centre.	at the Centre of Gravity.	above the Centre.	below the Centre.
even with the Axis.	Equipoise.	Necessary Parallelism.	Reversion.	Equipoise.	Necessary Parallelism.	Reversion.	Equipoise.	Necessary Parallelism.	Reversion.
above the Axis.	Reversion.	Reversion. Necessary Parallelism. | Equipoise.	Reversion.	Reversion.	Reversion. Necessary Parallelism. | Equipoise.	Reversion.	Reversion.	Reversion. Necessary Parallelism. | Equipoise.	Reversion.
below the Axis.	Necessary Parallelism.	Necessary Parallelism.	Reversion. Necessary Parallelism. | Equipoise.	Necessary Parallelism.	Necessary Parallelism.	Reversion. Necessary Parallelism. | Equipoise.	Necessary Parallelism.	Necessary Parallelism.	Reversion. Necessary Parallelism. | Equipoise.

The author farther describes the bowls of the balance, five in number. He advises to make them of very thin plates of bronze, and to give to three of them the form of hemispheres, measuring thirty divisions of the scale of the beam in diameter. The bowl destined to be plunged into water was finished at the bottom with a cone, in order that it might more easily overcome the resistance of the fluid during the immersion. The remaining bowl was spherical in shape. I here give the passage describing this last bowl, remarking only that it will be found not to correspond altogether with the figure *d* in the representation of all the bowls together, presently to be introduced, although evidently referring to that one.[32]

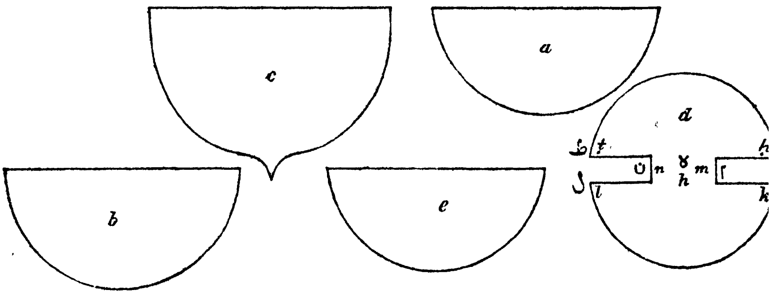
ثم ناخذ فنجانة رابعة على قطب ه قطرها ثلثون جزء شبيهة للهوائيّتين
ونحزّها من الجانبين بقدر خمسة اجزاء حزها نحو القطب الى وسط الحدبة
احدهما ط ن ل والاخر ح م ك ويكون البعد بين القطب الذى هو ه ونقطة
ن خمسة اجزاء وبين ه ونقطة م عشرة اجزاء ويسمى جانب ط ل الداخل
وجانب ح ك الخارج على ان يكون الباقى بين الحزين خمسة عشر جزء
من المعيار ثم ناخذ صفحة على حجم الفنجانة دقّة وندير عليها دايرة
تفتح فرجا وهو خمسة عشر جزء من المعيار ونحذف منها ما ورآءها ثم
نقطعها بنصفين مختلفين ونعقّف كل قسم منها ونلحمه على حرف كل
جانب منها واحدا ونسميها اللفة المجنحة

Then we take a fourth clepsydra, [turning] on an axis *h*, of which the diameter measures thirty divisions [of the scale of the beam], as does that of the two air-bowls; and we cut it on the two sides [of the axis], measuring five divisions [once and twice] in the direction of the axis, towards the centre of the bulge—of which cuts one is *ṭ n l* and the other *ḥ m k*—leaving, between the axis *h* and the point *n*, a distance of five divisions, and, between *h* and the point *m*, a distance of ten divisions, and calling *ṭ l* the inner side, and *ḥ k* the outer side; so that the remainder [of the diameter of the clepsydra] between the two cuts measures fifteen divisions of the standard-measure. In the next place, we take a thin plate [of bronze], as large as the clepsydra, and mark upon it a circle opening with a certain spread, namely, of fifteen divisions of the standard-measure, and cut off from that [plate] all that is outside of that [marked circle]; after which we cut that [circle] into two unequal parts, bend each part, and weld it, separately, to one of the outer edges of the two sides; and we call this the winged bowl.

Two of these bowls bore the name of "the aerial," الهوائيّة, and were permanently attached to the beam. Another bowl,

the right arm of the beam; it was called "the movable" bowl, المنقلة. The spherical bowl, also, was moved along the right arm. The bowl intended to be plunged into water was made fast underneath the aerial bowl of the left arm, and bore the name of "the aquatic" bowl, المائية. As to the spherical bowl, its name, sufficiently explained by its form, just now described, and given to it in the extract, was "the winged" bowl, المجنحة. Our author adds that it was indispensable to have at least one movable bowl, in order to balance the two which were used when the body weighed was plunged into the water.

The following is a copy of our author's drawing of these five bowls grouped together:



a. الكفة الاولى اليمنى

First, Right-hand Bowl.

b. الكفة الثانية اليسرى

Second, Left-hand Bowl.

c. الكفة الثالثة المخروطة يقال لها الحاكم

Third, Conical Bowl, called the Judge.

d. الكفة الرابعة المجنحة محزوزة الجانبين

Fourth, Winged Bowl, cut on the two sides.

t l. الجانب الداخل الانسى

Inner, Nearer Side.

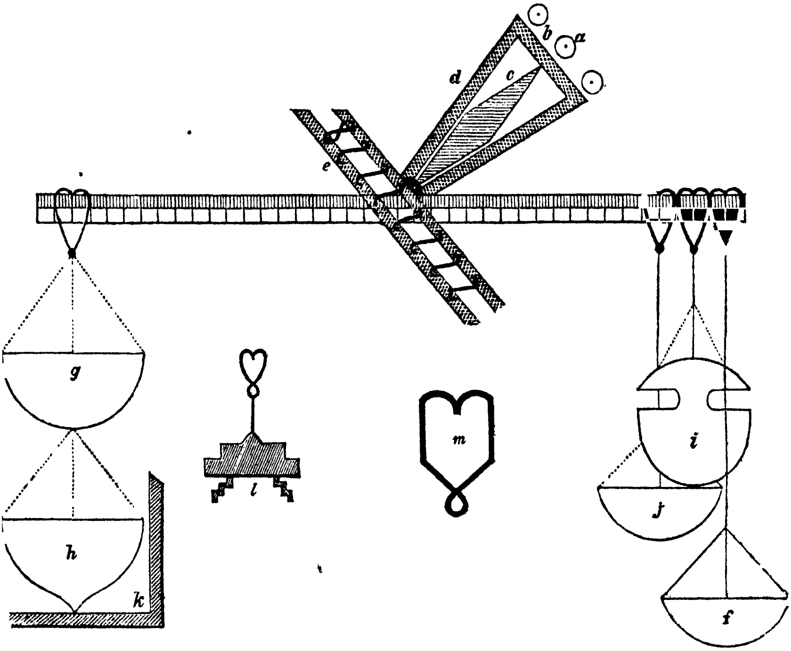
e. الكفة الخامسة كفة المنقلة

Fifth Bowl, which is the Movable Bowl.

Having devoted a paragraph to describing the form which should be given to the rings of suspension for the bowls, all of which are shaped like *m* in the figure on the next page, the author at length presents a complete drawing of the balance of wisdom. This we here reproduce, with all the accompanying explanations:[33]

صورة ميزان الحكمة المعروف بالجامع

Figure of the Balance of Wisdom, called the Comprehensive.



above, on the left:
النصف الايسر Left Half, for Substances.

above, on the right:
النصف الايمن للصنجات Right Half, for Counterpoises.

along the beam, on the left:
الشعيرات الظاهرة Plain Round-point Numbers.

along the beam, on the right:
الشعيرات الخافية Hidden[34] Round-point Numbers.

under the beam, on the right:
تثبت المراكز عليه فى هذا الجانب The Specific Gravities are marked on this Side of the Beam.

a. المعلاق Means of Suspension.

b. العريضة Front-piece.

c. اللسان Tongue.

d. [m5]الفياران Two Cheeks [of the Front-piece].

e, and under the beam on the left: العريضة واللسان[n5] بعد غير محكمين اذا الاحكام يأتى بعد الامتحان فى موضعه The Front-piece and the Tongue as disconnected [from the

f. الطرفية الهوائية Air-bowl for the End.

g. الطرفية الهوائية الثانية Second Air-bowl for the End.

h. كفة الماء الثالثة Third [or] Water-bowl.

i. المجنحة الرابعة Fourth [or] Winged Bowl.

j. المنقلة الخامسة Fifth [or] Movable Bowl

Beam], because they are not connected until after Experiment with regard to the Place of Connection.

k. السطل Basin.

l. الرمانة السيارة على النصف الشايل Pomegranate-counterpoise, which rides upon the Rising Half.

Our author recapitulates, briefly, his description of the different parts of the balance of wisdom, and then proceeds to speak, in detail, of the mode of adjusting it. Nothing of what he says on this point deserves to be cited. I will only borrow from it the observation that the Arab physicists were accustomed to mark the specific gravities of different bodies, on the right arm of the beam, by points of silver enchased at different places along the scale, where the movable bowl was to be put in order to counterbalance the loss of weight of different metals and precious stones when plunged into water. This accounts for the term الشعيرات, "round points," applied to marks of specific gravity upon the beam of the balance; and similar usage in respect to all marks of weight upon the beam led to the more general application of this term.

But, before proceeding to describe the application of this balance to the examination of metals and precious stones, as to their purity—which will bring out all the workings of the instrument—I think it incumbent upon me to transcribe and translate the following passage, which is, without doubt, one of the most remarkable in the whole work:

الفصل الخامس

فى وصية فيه

الزنة الهوائية لا تختلف اختلافا ظاهرا وان كان لا تخلو منه بسبب اختلاف
الاهوية واما زنته المائية فيظهر فيه تفاوت باختلاف مياه البقاع والابار
المستنقعات فى اللطافة والثخانة وما يعرض فيه من اختلاف الفصول والمنافع[05]
فيختار من المياه ماء بقعة معينة وبلد معروف ونرصد زنته المائية ونعلم

Section Fifth. [Lect. 5, Chap. 4.]

Instruction relative to the Application.

Air-weight does not apparently vary, although there is actual variation, owing to difference of atmospheres.

As regards its water-weight, a body visibly changes, according to the difference between waters of [different] regions, wells, and reservoirs, in respect to rarity and density, together with the incidental difference due to the variety of seasons and uses. So then, the water of some determined region and known city is selected, and we observe upon the water-weight of the body, noting exactly what it is, relatively to the weight of

ما يخصّ منها لزنة مأة مثقال وننسب العمل اليه ونحفظه وقت الحاجة اليها
ان شاء الله تعالى يجب ان يعمل فى الشتاء بالماء الفاتر دون البارد جدّا
لخثورته ومعاوقته الثقل فيخرج زنته المائية اقلّ مما يوجد فى الصيف
ولهذه العلة ايضا يرسب فنجانة الماء فيه اذا كان الماء صادق البرد بطيئا
واذا كان حارّا مسرعا وفيما بينهما لا ترسب كما[p5] اذا كان فاترا ولهذا اثر
بيّن فى الشتاء والصيف فلتحفظ هذه الاشياء وابو الريحان رحمه[q5] رصد
الفلزات والجواهر بزنتها المائية بجرجانية خوارزم فى اوايل فصل الخريف
والمياه معتدلة البرد واثبتها فى رسالة المذكورة

one hundred mithkâls; and we refer [all] operations to that [result, as a standard], and keep it in mind against the time when we are called upon to perform them, if the Supreme God so wills.

In winter, one must operate with tepid, not very cold, water, on account of the inspissation and opposition to gravity of the latter, in consequence of which the water-weight of the body [weighed in it] comes out less than it is found to be in summer. This is the reason why the water-bowl settles down when the water has just the right degree of coldness, and is in slow motion, while, in case it is hot and moving quickly, or of a lower temperature, yet warmer than it should be, the bowl does not settle down as when the water is tepid. *The temperature of water is plainly indicated, both in winter and summer;* let these particulars, therefore, be kept in mind.

'Abu-r-Raiḥân—to whom may God be merciful!—made his observations on the water-weight of metals and precious stones in Jurjânîyah [a city] of Khuwârazm, early in autumn, and with waters of middling coldness, and set them down in his treatise already spoken of.

This passage puts it beyond doubt that the Muslim natural philosophers of the twelfth century knew the air to have weight, though they were without the means of measuring it. The sentence italicized would lead one to believe that they had some means of measuring the temperature of water; and, not to resort to the supposition that they possessed any thermometrical instrument, even of the sort used by Otto Guericke, which was a balance, I think that they simply used the areometer for that purpose; and that this instrument was the means of their recognizing that the density of water is greater exactly in the ratio of its increase in coldness.

As a last citation of the words of the author whose work we have been analyzing, I shall transcribe and translate the passage in which he exhibits the application of the balance of wisdom to the examination of metals and precious stones, with regard to their purity. It is as follows:

الباب الرابع

فى العمل بالميزان الجامع

واذ قد فرغنا من امتحان الميزان واثبات المراكز عليه فقد[r5] لنا ان نخوض فى العمل به وامتحان خالص الفلزات والجواهر من جهة المركز بالمنقّلتين باهون سعى واقرب وقت من مختلطه واشباهه وملوّنه مفردا ومثنى دون مثلث وما ورآيه ركبنا كفتى الميزان الهوائيّتين والمائية فى الماء ثم نركب المنقّلة على مركز الجوهر[s5] المعطى ويعدل بالرمانة والمعيار[t5] حتى استوى لسانه هذا اذا كان الامتحان للمفردات واما اذا كان الامتحان للمختلط من جوهرين او الملون الموهوم ركبنا المنقلتين على مركزيهما ثم عدلناه غاية التعديل ثم اخذنا فى الامتحان

الفصل الاول

فى امتحان واحد واحد من المفردات بعد وضع المنقلة على مركز الفلز وتعديل الميزان

اذا اردنا ذلك وزنّا الجوهر وهو نحو اليسار والمثاقيل نحو اليمين فى الكفتين الهوائيّتين ثم ارسلناه الى الكفة المائية حتى يغوص فيه ويصيبه البلل من جميع

Chapter Fourth. [Lect. 6.]

Application of the Comprehensive Balance.

Having finished experimenting with the balance, and fixing upon it the [points indicating] specific gravities, it only remains for us to go into the application of it, and the trial of a [supposed] pure metal or precious stone, by means of the two movable bowls [that called "the movable" and "the winged"], reference being had to specific gravity, with the least trouble and in the shortest time, by way of distinguishing [such metal or precious stone] from one which is alloyed, or from imitations, or from its like in color—the substance being either simple or binary, not trinal, nor yet more complex.

We adjust the two air-bowls of the balance, put the water-bowl into the water, and then set the movable bowl at the [point indicating the] specific gravity of the given substance, and equilibrate by means of the pomegranate-counterpoise and the scale, until the tongue of the balance stands erect. Thus we proceed when the trial respects simple substances. When the trial is in reference to a mixture of two substances, or a fancy-likeness in color, we set the two movable bowls at the [two points indicating the] specific gravities of the two substances, and bring the balance to an equilibrium, with the utmost precision possible, and make the trial.

جهاته وفي جميع اجزائه وان اتّفق فيه ثقب او تجويف يجب ان يمتلى ماء
واجتهد الوزّان في ذلك ما في سعته من الاحتياط في ايصال الماء الى جميع
اجزائه الى ان لا يبقى فيه تجويف او ثقب فيه هواء لم يصل اليه الماء
لان حكم الخلاء في الجوهر كاختلاطه مع الاخفّ منه ثم نقلنا المثاقيل من
الطرفية الى المنقلة الموضوعة على مركزه فان اعتدل الميزان واستوى
ولم يمل الى جانب فهو هو خالصا ان كان فلزا او جوهرا حجريا وان مال
الى جانب فليس هو هو ان كان حجريا واما الفلز فليس هو خالصا وانما شابه
غيره فان كان الشول لجانب المثاقيل فاختلط بالجرم الاخفّ وان كان لجانب
الفلز فبالاثقل منه واما اذا لم يشبه غيره ففيه تمويه ومعاناة مجوّف ذو هواء
وشقوق او ما اشبه ذلك من الحيل فليحترز منه وليظهره بالطرق للفلزات

Section First.

Trial of Single Simple Substances, after placing the Movable Bowl at the [Point indicating the] Specific Gravity of the Metal [or Precious Stone], and after the Poising of the Balance.

When that is the trial which we wish to make, we weigh the substance—it being on the left, and the mithkâls on the right, in the two air-bowls; then we let it down into the water-bowl, until it is submerged, and the water reaches all sides and penetrates all parts of it. If there happens to be a perforation or a hollow place in it, that must be filled with water; and the weigher endeavors to have it so, taking all possible care that the water reaches all its parts, in order that there may remain in it no hollow place, nor perforation, containing air, which the water does not penetrate, because a void place in the substance has the same effect as if it were mingled with something lighter than itself. After this we transfer the mithkâls from the extreme bowl [on the right] to the movable bowl, placed at the [point indicating the] specific gravity of the substance; whereupon, if the balance is poised, and stands even, not inclining any way, the substance is what it is [supposed to be], pure, whether a metal or a precious stone. Should the balance lean any way, the substance is not what it is [supposed to be], if a precious stone; and, as to the case of a metal, it is not purely that, but only something like it, different from it. If the rising [of the beam] is on the side of the mithkâls, the substance [being a metal] is mixed with some body heavier than itself; if on the side of the substance, then with some lighter body.

On the other hand, since the substance may not be an imitation, but may have been tampered with, and expressly made hollow, blown with air, fissured, or the like, trickishly, let that be looked out for, and made manifest, with regard to metals, by striking them.

الفصل الثانى

فى امتحان ثنائى المركب من اثنين اثنين اى من فلزى مثل الذهب ومنه
معرفة عيار الدراهم والدنانير

فانا نركب المنقلتين بعد تركيب الطرفيتين والمايية على مركزى الفلزين
المظنونين او احديهما على مركز الجوهر الحجرى والاخرى على ملونه من
بلّور او زجاج ثم نعدل الميزان غاية التعديل حتى استوى لسانه ثم وزنّاه
فى الهوائيتين غاية الاستقصاء ثم احدرناه فى الكفة المايية واستقصينا فى
وصول الماء الى جميع اجزايه هذا فى وسع الوزان لتجاويفه الظاهرة او
الطرق حيث امكن لرفع التهمة ثم نقلنا المثاقيل الى المنقلة التى على
مركزه ونظرنا الى الميزان فان اعتدل فهو هو خالصا وان لم يعتدل نقلناها
الى المنقلة الاخرى فان استوى اللسان فهو من جنس المركز مغشوشا
ملونا وهذا فى الجواهر الحجرية خاصة لا يخلو اما ان يكون هذا او ذلك

Section Second.

Trial of a Binary, made up of any two Substances [supposed], e. g. of two Metals, and similar to Gold; whereby the Assignment of their True Value to Dirhams and Dînârs is determined.

After having adjusted the two extreme bowls and the water-bowl, we set the two movable bowls at the two [points indicating the] specific gravities of the two metals supposed, or, one of them at the [point indicating the] specific gravity of a precious stone, and the other at [the point indicating the specific gravity of] its like in color, crystal or glass; and then we poise the balance, with the utmost exactness, until its tongue stands erect. Then we weigh the body [under examination] with the two air-bowls, taking the greatest care; and in the next place dip it into the water-bowl, being careful that the water reaches all its parts—which is a matter that the weigher can manage, as it respects void places in sight, or seams, so as to be able to remove uncertainty—after which we transfer the mithkâls [from the air-bowl on the right hand] to the movable bowl suspended at the [point indicating the] specific gravity [of one of the two substances supposed], and watch the balance. If the balance is in equilibrium, the body is that substance, pure. If it is not even, we transfer the mithkâls to the other movable bowl; and if the tongue then stands erect, the body is a colored imitation, having naturally the [latter] specific gravity. These remarks apply especially, though not exclusively, to precious stones.

In the case of metals, when neither movable bowl brings the balance to an equilibrum, the body is compounded of the two [metals supposed]; and, if we wish to distinguish [the quantity of] each compo-

واما فى الفلزات اذا لم يعتدل فى المنقلتين جميعا فهو مركب منهما فاذا اردنا تمييز ما فى المختلط من كل واحد منهما فانا وزعنا المثاقيل بين المنقلتين مرّة بعضها الى المنقلة وبعضها الى المجنحة ونظرنا فان شال الجانب الايمن نقلنا من قريبيهما[u5] الى اللسان الى بعديهما[v5] وان مال نقلنا من البعدى الى القربى[w5] وهكذا يجعل دايما الى ان يعتدل الميزان فبعد الاستواء نظرنا الى ما فى كفة مركز الفلز من المثاقيل فهى فى المركب منه وما فى الاخرى فباقيه منه وان تعذر التوزيع بينهما بالمثاقيل دقة فانا نأخذ زنة المثاقيل من الرمل المكى فاذا اعوزنا الرمل فالبزور المنقّاة تنوب منابه ونوزعه بينهما فاذا اعتدل وزنّا ما فى كل منقلة منهما فيحصل على غاية الصحّة واما اذا لم يعتدل الميزان لا فى الاول ولا فى الثانى ولا بالتوزيع فيما بينهما فالمركب اما ليس من الجوهرين المذكورين واما مركب من ثلاثة جواهر واكثرها او فيهما تمويه ومعاناة شقوق[x5] او مجوف ومن التجويف نقل

nent of the mixture, we distribute the mithkâls, at once, between the two movable bowls [suspended at the two points indicating the specific gravities of the two metals supposed], giving some of them to the movable bowl [so called], and some of them to the winged bowl, and watch. If, then, the right side [of the beam] goes up, we transfer [mithkâls] from the bowl nearer to the tongue to that which is farther from it; and, if the right side goes down, we transfer mithkâls from the farther bowl to the nearer; and so on, until the balance is in equilibrium. Then, after it is even, we look to see how many mithkâls are in the bowl [suspended at the point] of the specific gravity of a [supposed] metal, and those constitute the weight of that metal in the compound; and the mithkâls in the other bowl constitute the weight of the other component. If we fail to distribute exactly between the two bowls by mithkâls, we take the weight of the mithkâls in Makkah-sand, or, when sand is not to be had, sifted seeds supply its place; and we distribute the sand [or seeds] between the two bowls. When the balance is brought to an equilibrium, we weigh what is in each of the two movable bowls, and so is obtained a result as perfect as can be.

Should the balance not be made even in either the first or the second instance [namely, by putting all the mithkâls in one or the other of the two movable bowls], nor by distribution [between the two bowls], then the compound either does not consist of the two substances which may have been mentioned, or is composed of three or more substances; or else the two [as compounded together] have been tampered with, and purposely fissured or hollowed. A cavity gives occasion for transfer of gravity and weight. One must be careful and considerate, therefore; and

ثقله ووزانته فيجب ان يحتاط ويتأمل فيه ووجه التأمل ان تنظر فان
شال احد الجانبين ونقل الثقل الى الاخرى شال ايضا هذا الجانب فقد
تحقق ما ذكرناه من التمويه واما اذا شال احد الجانبين فاذا نقل شال
الجانب الاخر فهو مركب منهما فيجب ان يوزع وصية ويجب ان يحترز
عن تلبيس الجسم فى الثانى منه مثل المركب من الذهب والفضة ويجعل فى
خلاله تجويفا لا يقاوم الذهب ويرده الى خفة الفضة ويحوّل زنته الى كفة
الفضة والحق يكون بخلافه بسبب التجويف

the way to be considerate is to watch [the balance]. If, now, one of the two sides [of the beam] goes up, and if, upon the transfer of gravity to the other movable bowl, this side still goes up, the tampering which we have spoken of is made certain. If one of the two sides goes up, and then, when there has been a transfer [of gravity], the other side goes up, the body is compounded of the two substances.

The distribution [of weight] must be made agreeably to instructions; and one must beware of being deceived in the second case concerning it, for example, in the case of a compound of gold and silver [supposed, but not proved by distribution]; and, considering that there may be some hollow place within, which opposes [the discovery in it of] gold, and makes it [appear as if] of the lightness of silver, one should remove its weight to the bowl [adjusted] for silver; whereupon, by reason of a hollow place, one's conclusion may be changed.

It is evident from this passage that the Muslim natural philosophers of the twelfth century had so elaborated the balance as to make it indicate, not only the absolute and the specific gravity of bodies, but also, for bodies made up of two simple substances, a quantity dependent on the absolute and the specific gravity, which may be expressed by the formula

$$x = W \frac{\frac{1}{d'} - \frac{1}{s.\,gr.}}{\frac{1}{d'} - \frac{1}{d''}},$$

where W is the absolute weight of the body examined, $s.\,gr.$ its specific gravity, d', d'' the densities of its two supposed components, and x the absolute weight of the latter component.[35] In order to accomplish that object, however, they were led to make their balance of enormous dimensions, such as rendered it very inconvenient for general researches.

I will bring this analysis to a close by a concise exposition of the manner in which the Muslim natural philosophers applied the balance to levelling and to the measuring of time.

The balance-level consisted of a long lever, to the two ends of which were attached two fine silken cords, turning on an axis fixed at a point a little above its centre of gravity, and suspended between two sight-pieces of wood, الكشب, graduated. At the moment when the lever became horizontal, the cords were drawn in a horizontal direction, without deranging its equilibrum, and the divisions of the scales of the sight-pieces, corresponding to the points where the cords touched them, were noted. For levelling plane surfaces, use was made of a pyramid with an equilateral, triangular base, and hollow and open to the light, from the summit of which hung a thread ending with a heavy point. The base of the pyramid thus arranged was applied to the plane which was to be levelled, and carried over this plane in all directions. Wherever the plane ceased to be horizontal, the point deviated from the centre of the base.

The balance-clock consisted of a long lever suspended similarly to the balance-level. To one of its arms was attached a reservoir of water, which, by means of a small hole perforated on the bottom of it, emptied itself in twenty-four hours. This reservoir, being filled with water, was poised by weights attached to the other arm of the lever, and, in proportion as the water flowed from it, the arm bearing it was lifted, the weights on the other arm slid down, and by their distance from the centre of suspension indicated the time which had elapsed.

Recapitulating, now, briefly, the results brought out in this analysis, we see:

1. That the Muslim natural philosophers of the twelfth century were much in advance of the ancients as regards their ideas of attraction. It is true, they ventured not to consider this attraction as a universal force; they attributed to it a direction towards the centre of the earth, as the centre of the universe; and they excluded the heavenly bodies from its influence.[36] Yet they knew that it acts in a ratio of distance from the centre of attraction. As to their strange supposition that the action of this force is in the direct ratio of the distance, having gone so far as they had in physics, they must very soon have discovered that it was not in accordance with nature.

2. That they had sufficiently correct ideas respecting certain mechanical principles; that they knew the equation which connects velocity with space traversed and time employed in going over it; that they were in possession of several theorems relative to centres of gravity; and that the theory of the loaded lever was very familiar to them.

3. That, without yet daring to reject the ideas which had been handed down to them by antiquity as to heaviness and lightness,

they already recognized that the air has weight, by the influence which it exerts upon the weight of bodies.

4. That they observed the action of a capillary force holding liquids in suspension within tubes of small diameters, open at both ends.

5. That they made frequent use of the areometer, which they had inherited from antiquity, and that this instrument, very probably, served them for a thermometer, to distinguish, by difference of density, the different temperatures of liquids.

6. That they already had sufficiently full and accurate tables of the specific gravities of most of the solids and liquids known to them.

7. That they had attained, as Baron v. Humboldt very correctly remarks, to experimentation; that they recognized even in a force so general as gravity, acting upon all the molecules of bodies, a power of revealing to us the hidden qualities of those bodies, as effective as chemical analysis, and that weight is a key to very many secrets of nature; that they formed learned associations, like the Florentine Academy; and that the researches of the students of nature in Khuwârazm, of the twelfth century, well deserve to be searched for and published.

Here an inquiry very naturally suggests itself. It is generally known that, at the time when the taste for arts and sciences awoke to so brilliant a life in Europe, the Arabs powerfully influenced the development of several of the sciences. How comes it, then, that their progress in physics can have remained so completely unknown to the learned of Europe? The answer seems to me perfectly simple. The immense extent of the Khalîfate was a cause which produced and perpetuated the separation and isolation of the interests of the various heterogeneous parts which composed it. A philosopher of Maghrib would doubtless understand the writings of a philosopher of Ghaznah; but how should he know that such a person existed? The journeys so often undertaken by the Arabs were insufficient to establish a free interchange of ideas; even the pilgrimage to Makkah, which brought together every year representatives of all the nations subject, whether willingly or unwillingly, to the law of the Muslim Prophet, failed, by reason of its exclusive character, to modify in any degree that separation of moral interests which kept the different Muslim countries apart from one another. Moreover, the crusades had an effect to intercept communication between the Muslim East and West. At length, the Mongol and Turkish invasions split the Muslim world into two parts, wholly estranged from one another, and, so to speak, shut up the scientific treasures of each part within the countries where they were produced. If, now, we reflect that the era of the renaissance in Europe precisely coincides with that same invasion of the Turks, we shall

clearly see why Europe could scarcely at all profit by the scientific monuments of the East of the Khalîfate, and why the scientific experience of true Orientals has been almost entirely withdrawn from its notice.

Let me be allowed, in conclusion, to add a single observation, which is, that it is an error to attribute to Arab genius all the great results that the East has attained in the sciences. This error rests upon the fact that most of the scientific treatises of Orientals are written in the Arabic language. But would language alone authorize us to give the name of Roman to Copernicus, Kepler, and Newton, to the prejudice of the glory of those nations which gave them birth? Should, then, 'al-Ḥamadânî, 'al-Fîruzabâdî, 'al Khaiyâmî, and many others, figure in the history of science as Arabs, only because they enriched the literature of this people with the Maḳâmât, the Ḳâmûs, expositions of the Ḳurân, physical researches, and algebraic treatises? It would be more just, as it seems to me, to restore these to the Iranian race, and to suppress the injuriously restrictive name of Arab civilization, substituting for it that of the contribution of the Orient to the civilization of humanity.

Nihmat-Abad, $\frac{\text{28 Oct.}}{\text{9 Nov.}}$, 1856.

Notes by the Committee of Publication.

Besides re-translating the Arabic extracts in the foregoing article, and making other changes which are specified in the following notes, we have freely altered whatever seemed to us to admit of improvement, being desirous to do full justice to so valuable a communication, according to our best judgment and that of scientific friends who have aided us, and fully believing that our correspondent, if we could have consulted him, would have approved of every alteration which we have made.

Comm. of Publ.

I. Notes on the Text.

Referred to by Letters.

Page.

4. l. 8, ***a***, ms. تجربة; l. 11, ***b***, ms. قضيّة.

6. l. 3, ***c***, ms. جديدها.

8. l. 11, ***d***, الاولى omitted in ms.

11. l. 6, ***e***, ms. المتعارفية; l. 9, ***f***, ms. والطبيعة; l. 14, ***g***, ms. ذكرناها, ***h***, ms. لها.

Page.

12. l. 6, *i*, ms. ذوماطيانوس ; l. 8, *j*, ms. لايارن ; l. 13, *k*, ms. ايارن.

13. l. 6, *m*, ms. بن ; l. 14, *n*, ms. الاسفرازى , and so wherever else the name occurs.

15. l. 1, *o*, ms. موضعها ; l. 4, *p*, ms. الجوهر ; l. 11, *q*, الدين omitted in ms.

16. l. 13, *r*, ms. انساب.

17. l. 2, *s*, ms. منه ; l. 7, *t*, ms. منه.

18. l. 6, *u*, ms. والطبيعة ; l. 8, *v*, ms. المصرى—see note **3**, p. 111.

19. l. 3, *w*, خمسة ابواب omitted in ms.

20. l. 11, *x*, ms. ميلاوس.

21. l. 2, *y*, اربعة ابواب omitted in ms.; l. 12, *z*, ا omitted in ms., and so wherever else this numeral appears in the table of contents.

22. l. 3, a^2, ms. المركب ; l. 9, b^2, ms. بعضها ; l. 11, c^2, ms. الهوى.

23. l. 5, d^2, ms. ثمانية—This correction is required by the statement of the contents of the second and third parts of the work given on page 17; l. 11, e^2, ms. خمسة—see preceding note. The numbering of the chapters of this lecture has been altered in accordance with the corrections of the text here made.

24. l. 10, f^2, ms. خمسون for تسعة واربعون , g^2, ms. ماة وخمسون —A collation of the whole ms. from which our extracts are made is necessary to verify this statement. Some of the numerals indicating the numbers of sections are obscurely written in the ms. which we have in our hands; and, though our correspondent's analysis has given us certainty in some of the doubtful cases, it still remains uncertain whether the number of sections in chh. 1 and 3 of lect. 4, chh. 4 and 10 of lect. 6, and ch. 4 of lect. 7 is ج i. e. 3, as stated, or ح i. e. 8. We have also doubted whether to read ز i. e. 7, or د i. e. 4, for the number of sections in ch. 5 of lect. 8; and what value to assign to a character, repeatedly used, which resembles the letter ع. In our ms. of the table given on pages 73, 74, the same character is used for 0, but of course this is not its value in the table of contents. From its similarity to the Indian numeral for 4, and because in one instance the letter د seems to be added to explain it, we have assigned to it that value. On the grounds assumed, the total number of sectious comes out larger, by twenty-one, than the statement of our ms.

26. l. 6, h^2, ms. القونى—see note **3**, p. 111; l. 7, i^2, ms. ‟ see note **3**, p. 111; l. 9, j^2, الاول omitted in ms.

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30. l. 6, k^2, ms. ومعادلة ; l. 10, l^2, ms. مركز.

32. l. 8, m^2, ms. مركز.

33. l. 10, n^2, ms. اعظمها.

35. l. 2, o^2, ms. فاعظمهما.

36. l. 4, p^2, ms. لا جرمه , a fragment of a sentence, which we have completed as in the text: الخامس يسفو بقدر قوته لا بقدر جرمه in accordance with the French translation of our correspondent.

37. l. 2, q^2, ms. مقام ; l. 3, r^2, ms. اعظمها.

38. l. 6, s^2, ms. انية, t^2, ms. الماء ; l. 7, u^2, ms. الانية, v^2, ms. ويسع ; l. 8, w^2, ms. الانية ; l. 9, x^2, ms. اذا, y^2, ms. كان ; l. 10, z^2, ms.

43. l. 12, a^3, ms. تحتها.

45. l. 9, b^3, ms. خمسماتها.

48. l. 3, c^3, ms. الشبيهة ; l. 4, d^3, ms. قاعدة.

49. l. 9, e^3, كما العدد المحفوظ الى ثقل الماء supplied to complete the sense.

51. l. 2, f^3, ms. منها ; l. 6, g^3, ms. الثقيلة—by an oversight of the copyist, الثقيلة and الخفيفة in this sentence were transposed ; l. 7, h^3, ms. الرطوبة ; l. 12, i^3, ms. اثقل ; l. 15, j^3, الى وزن الرطوبة التى رسب فيها الى فى بالتكافى supplied to complete the sense ; l. 16, k^3, ms. اخ.

52. l. 4, l^3, ms. تم باب مقياس المايعات وتمت المقالة الاولى لفوفس الرومى.

55. l. 16, m^3, ms. باذوبنه.

59. l. 4, n^3, ms. ماء, o^3, ms. ارض, p^3, ms. او البقرك والنكلس, q^3, ms. واحتراق.

61. l. 7, r^3, ms. مرجه.

63. l. 2, s^3, ms. اليواقيت ; l. 7, t^3, ms. البدخشى ; l. 9, والزبرجد supplied to make out the sense.

64. l. 12, u^3, ms. اجتماعها.

65. l. 3, v^3, ms. البجرية ; l. 12, w^3, ms. البدخشى ; l. 17, x^3, ms. ثلثة.

66. l. 1, y^3, الفصل الثانى omitted in ms.

69. l. 7, z^3, ms. البدخشى ; l. 10, a^4, ms. لا شى ; l. 13, b^4, ms. اثنان.

70. l. 5, c^4, ms. والراط ; l. 8, d^4, ms. تراب, e^4, ms. هواء ; l. 9, f^4, ms. هواء.

72. l. 4, g^4, ms. بعضها.

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73. l. 2, h^4, ms. ومايُها ; l. 3, i^4, ms. وهيهنا ; l. 6, j^4, ms. من ; l. 8, k^4, ms. السمنكانى .

75. l. 1, l^4, before الباب الرابع ms. has القسم الثانى فى مقياس الماء ومقدار ملاء الارض ذهبا وهو. But the second division of the book commences with the fifth lecture—see p. 17; and ... فى مقياس is evidently a blundering anticipation of the title of this fourth chapter of the third lecture.

76. l. 1, m^4, ms. عدّ ; l. 4, n^4, ms. ثمانية ; l. 6, o^4, مضروب substituted for a word illegible in ms.; l. 7, p^4, ms. ۴۸۹۷۹۲ ; l. 12, q^4, ms. وخمسين ; l. 13, r^4, ms. خمس عشرة , s^4, ms. مياه.

77. l. 1, t^4, ms. المرات ; l. 13, u^4, مايتين omitted in ms.; l. 14, v^4, for وثمانية وعشرين استارا ms. has وستّة اساتير ونصف وربع وخمس ونصف ; l. 15, w^4, ms. ماة , x^4, ms. كلفر.

78. l. 1, y^4, ms. متقال ; z^4, ms. مثاقيل ; a^5, ms. مايُها ; l. 3, b^5, ms. ۹۷۹۳۵۵۳ ; l. 4, c^5, ms. ذراعا ; l. 6, d^5, ms. استار.

87. l. 33, e^5, ms. الفنارين.

89. l. 5, f^5, ms. تقله.

90. l. 6, g^5, ms. العالم ; l. 7, h^5, ms. الموازاة.

92. l. 9, i^5, ms. ثمانية عشر—This correction is required by the multiplication together of the numbers of the incidents combined. The enumeration just made involves nine specifications relative to the position of the axis, covering the two cases of separation and connection between the tongue and beam, and also the two cases supposed with regard to the position of the tongue when joined to the beam; and this number nine is multiplied by the number of the specifications respecting the position of the line of suspension of the bowls.

93. j^5, ms. كفة ; k^5, ms. مستوى ; l^5, ms. مقلوب.

97. l. 15, m^5, ms. الفنارين ; l. 18, n^5, ms. سلسان.

98. l. 29, o^5, ms. المواضع.

99. l. 5, p^5, كما omitted in ms.; l. 6, q^5, رحمه conjectural for an abbreviation of the ms.

100. l. 3, r^5, ms. فقد ان ; l. 7, s^5, ms. الجواهر ; t^5, ms. او المعيار.

103. l. 4, u^5, ms. اقربهما , v^5, ms. ابعدهما ; l. 5, w^5, for البعدى الى القربى ms. has القربى الى البعدى ; l. 12, x^5. ms. ستوق.

N. B. Some necessary changes of diacritical points are not here noticed. The original ms., it will be remembered, is without these points.

II. Notes on Translation and Analysis.

Referred to by Numerals.

1, p. 20. The length of the cubit, الذراع, was somewhat variable. We read (1.) of ذراع اليد, the hand-dhirâ', of the Spanish Arabs, measuring five قبضات, fists, each ḳabḍhah of four اصابع, fingers; (2.) of the dhirâ' called الرشاشية—cubitus a situlâ cujus magnitudinem aequat ita dictus, as Casiri says—used in Spain, which measured six ḳabḍhahs; (3.) of ذراع اليد العادلة, the exact-hand dhirâ', used in the East, having the same length as the last named; (4.) of الذراع السوداء, the black dhirâ', so called because, as is said, its length was determined by that of the arm of a slave of 'al-Mâmûn, measuring six fists and three fingers, and by which were sold the byssus and other valuable stuffs of the bazaars of Baghdâd; and (5.) of the dhirâ' called الهاشمية or الملكية, of Persian origin, measuring one and a third of No. (3.), that is, eight fists. Our author elsewhere speaks definitely of ذراع اليد, by which he probably intends ذراع اليد العادلة, and of the dhirâ' of clothing-bazaars. What he calls the dhirâ', without qualification, is probably to be understood as No. (5.). See Casiri's Bibl. Arabico-Hisp., i. 365, ff.; and Ferganensis . . . Elem. Astron. op. J. Golii, pp. 73, 74.

2, p. 24. This term is explained by the figure of the رمانة given on page 97.

3, p. 25. Having satisfied ourselves that M. Khanikoff's conjecture as to the authorship of the work before us is incorrect, we propose simply to give the substance of it in this note, in connection with what seems to us to be the true view. But we will first bring together a few notices of learned men whom our author speaks of as his predecessors in the same field of research, who are not particularly referred to in M. Khanikoff's note on pages 24, 25.

Sand Bin 'Alî is characterized by an Arab author quoted by Casiri, in Bibl. Arabico-Hisp., i. 439, 440, as follows: "An excellent astronomer, conversant with the theory of the motion of the stars, and skilled in making instruments for observations and the astrolabe. He entered into the service of 'al-Mâmûn to prepare instruments for observation, and to make observations, in the quarter called 'ash-Shamâsîyah at Baghdâd; and he did accordingly, and tested the positions of the stars. He did not finish his observations, on account of the death of

'al-Mâmûn. With him originated a well known astronomical table, which astronomers make use of to our day. Having been a Jew, he became a Muslim by the favor of 'al-Mâmûn. Several well known works on the stars and on arithmetical calculation were written by him."

Respecting Yûḥannâ Bin Yûsif, Casiri, Id., i. 426, quotes the following from an Arab author: "Yûḥannâ the Christian presbyter, Bin Yûsif Bin 'al-Ḥârith Bin 'al-Baṭrîḳ was a savant distinguished in his time for lecturing on the Book of Euclid, and other books on geometry. He made translations from the Greek, and was the author of several works."

'Ibn 'al-Haitham of Baṣrah, whose full name was 'Abû-'Alî Muḥammad Bin 'al-Ḥasan 'Ibn 'al-Haitham of Basrah, as we are told by Wüstenfeld in his Gesch. d. Arab. Aerzte u. Naturforscher, pp. 76, 77, was a good mathematician as well as skilled in medicine. He rose to eminence in his paternal city of Baṣrah, but, on the invitation of the Fâṭimite Khalîf 'al-Ḥâkim, A. D. 996–1020, went to Egypt to execute some engineering, for the irrigation of the country when the Nile should rise less high than usual. In this undertaking he failed. The latter part of his life was devoted to works of piety and to authorship. He died at Cairo, A. H. 430, A. D. 1038. Our ms. gives him the title المصرى, but, as he was generally called from his native city, and the other title might so easily be an error of the ms., we have altered it to البصرى.

From an Arab author, again, quoted by Casiri, Id., i. 442, 443, we derive the following notice of 'Abû-Sahl of Kûhistân: "Wîjan Bin Wastam 'Abû-Sahl of Kûhistân was a perfect astronomer, accomplished in knowledge of geometry and in the science of the starry heavens, of the highest eminence in both. He distinguished himself under the Buwaihide dynasty, in the days of 'Aḍhad 'ad-Daulah [A. D. 949–982—see Abulfedae Annales Musl. ed. Reiske, ii. 454, 550]. After Sharf 'ad-Daulah had come to Baghdâd, on the expulsion of his brother Ṣamṣâm 'ad-Daulah from the government of 'Irâḳ [A. D. 986—see Abulf. Ann., ii. 560], he ordered, in the year 378, that observations should be taken on the seven stars, in respect to their course and their passage among their Zodiacal signs, as 'al-Mâmûn had done in his day, and he committed the accomplishment of this task to 'Abû-Sahl of Kûhistân. Consequently, the latter built a house within the royal residence, at the end of the garden, and there made instruments which he had contrived, and afterwards took observations which were written out in two declarations, bearing the signatures of those who had been present, in affirmation of what they had witnessed and were agreed in."

To this supplementary note we will only add that we could not hesitate to translate the name of the person to whom Menelaus is said to have addressed one of his books, which our correspondent failed to identify, namely دوماطيانوس, by Domitian. As the emperor Domitian reigned from A.D. 81 to 96, Menelaus must have been living in his time.

Respecting the authorship of the Book of the Balance of Wisdom, after observing that, although the dedication proves it to have been composed at the court of the Saljûḳe Sulṭân Sanjar (who reigned over a large part of the ancient Khalîfate of Baghdâd from A.D. 1117 to 1157), the recent developments of the history of the Saljûḳes by Defrémery afford no clue to the identification of the author, our correspondent quotes a passage from Khondemîr's Dustûr 'al-Wuzarâ' which he thinks may possibly allude to him, as follows: "Nâṣir 'ad-Dîn Maḥmûd Bin Muẓaffar of Khuwârazm was deeply versed both in the sciences founded in reason and in those based upon tradition, and was especially able in jurisprudence after the system of 'ash-Shâfi'î; at the same time he was famed for his knowledge of finance and the usages and customs of the public treasury. He was the constant protector of scholars and distinguished men. The Kâḍhi 'Umar Bin Sahlân of Sâwah dedicated to him his work entitled Maṣâ'ir-i-Nâṣirî, on physical science and logic. In the Jawâmi' 'at-Tawârikh it is stated that Nâṣir 'ad-Dîn commenced his career as secretary of the administration of the kitchens and stables of Sulṭân Sanjar, and that, as he acquitted himself creditably in that office, the Sulṭân named him secretary of the treasury of the whole kingdom, and he reached at length the high dignity of Wazîr, but, on account of the modesty common to men of studious habits, and which was native to him, he could not properly perform the duties attached to it. The Sulṭân accordingly discharged him from it, and again entrusted to him the administration of the finances, which he transmitted to his son Shams 'ad-Dîn 'Alî." On this passage M. Khanikoff remarks: "I do not pretend by the aid of this passage to establish irrevocably that Nâṣir 'ad-Dîn is the author of the treatise before us. But his being a Khuwârazmian accords with what our author says of the place where he made his researches; his participation in the administration of the finances would explain his having composed a work for the king's treasury; and lastly, the positive testimony of history as to his erudition . . . and the dedication to him of a work treating of physics give some probability to the supposition that he may have occupied himself with the subject. The absence of any direct notice of this treatise on the balance in his biography may be ascribed in part to the predilection of Khondemîr for politics rather than literary history, in consequence of

which he rarely mentions the scientific labors of those whose memoirs he gives, and partly to the circumstance that a work destined for the royal treasury, like official reports of the present day, might remain a long time unknown to the public."

We have thought it proper thus to give the substance of our correspondent's conjecture. But there can be no doubt that, in the extracts from the Book of the Balance of Wisdom which M. Khanikoff has given us, the author names himself three times, though in so modest a manner as scarcely to attract attention. Instead of heralding himself at once, in his first words, after the usual expressions of religious faith, as Arab authors are wont to do, he begins his treatise by discoursing on the general idea of the balance, with some reference, as it would seem, to the Bâṭinian heresy, which gave so much trouble to the Saljûḳe princes, and then simply says: "Says 'al-Khâzinî, after speaking of the balance in general . . ."—see p. 8, and proceeds to enumerate the advantages of the balance of wisdom, so called, which he is to describe and explain in the following work. Farther on, after a section devoted to a specification of the different names of the water-balance, and to some notices of those who had treated of it before him, he begins the next section thus: "Says 'al-Khâzinî, coming after all the above named . . ."—see p. 14, and goes on to mention certain varieties in the mechanism of the water-balance. The form of expression which he uses in the latter of these two passages implies that 'al-Khâzinî is no other than the author himself; for Arabic usage does not allow يقول to be employed to introduce what one writer quotes from another, though nothing is more common than for an author to use the preterit قال, with his name appended, to preface his own words. Besides, if 'al-Khâzinî is not our author, but one of those from whom he quotes, who had previously treated of the water-balance, why did he not name him in the section appropriated to the enumeration of his predecessors in the same field of research? In the title to a table which our correspondent cites in the latter part of his analysis, we read again: "Table etc. added by 'al-Khâzinî"—see p. 69, which also intimates the authorship of the work before us, for the writer introduces that table as supplementary to one which he cites from another author. Yet farther, if our author's name be really 'al-Khâzinî, his statement respecting the destination of his work for the royal treasury—see p. 16—accords with his own name, for 'al-Khâzinî signifies "related to the treasurer," and, as M. Khanikoff well observes, "the Orientals show as much jealousy in affairs of state as in their domestic concerns."

Who, then, is our 'al-Khâzinî? Though unable to answer this question decisively, we will offer some considerations with reference to it.

Possibly our author is the individual of whom D'Herbelot makes this record: "Khazeni. The name of an author who invented and described several mathematical instruments, of which he also indicated the use"—see Bibl. Or., p. 504. Or he may be the same as 'Abû-Jafar 'al-Khâzin, of whom an Arab author, quoted by Casiri, says: "'Abû-Jafar 'al-Khâzin, a native of Persia, distinguished in arithmetic, geometry, and the theory of the motion of the stars, conversant with observations and their use, famed in his day for this sort of knowledge. He was the author of several works, among which is the Book of the Zîj-'aṣ-Ṣafâ'iḥ (كتاب زيج الصفايح), the most eminent and elegant work on the subject, and the Book of Numerical Theorems (كتاب المسايل العددية)"—see Bibl. Arabico-Hisp., i. 408. Von Hammer, apparently on the authority of Sédillot, fixes his death in A. D. 1075—see Literaturgesch. d. Araber, vi. 428. Or our author may be identical with Alhazen, a person long known by name as the author of a treatise on optics translated by Risner, and published at Basel in 1572. It is also possible that one and the same individual is referred to under these several names. Risner intimates to us the original title of that treatise on optics in these words: "et ut inscriptionem operis, *quæ authori est de aspectibus*, græco, concinniore et breviore nomine opticam nominarem;" and we hoped to be able to obtain from Hâji Khalfah's lexicon some information respecting other works by the same author, which should throw light upon the authorship of the work before us. But this clue to a reference proved insufficient, and after several fruitless searches we have not found any notice by Hâji Khalfah of the famous optician. As to the period when Alhazen lived, Risner declares himself ignorant, but supposes that it was about A. D. 1100: it will be remembered that our author wrote in 1121. That our 'al-Khâzinî was a native of Persia, as is asserted of 'Abû-Jafar 'al-Khâzin, there is some reason to suppose, from his occasional use of Persian words; and here it may be well to observe that it is only by an error that Alhazen the optician is made a native of Baṣrah: the error is to confound him with Ḥasan Bin 'al-Ḥasan Bin 'al-Haitham of Baṣrah, which has been widely spread, though corrected by Montucla and Priestley—see Gartz, De Interpp. et Explanatt. Euclidis Arab., p. 22. The subject of the work before us is one which the Arabs were accustomed to class, with optics and other sciences, under the general head of geometry—see preface to Hâji Khalfah's lexicon, ed. Fluegel, i. 35; and there is, indeed, a little sentence in our author's introduction, which, with reference to the time when it was written, would seem even to betray a writer addicted to philosophizing on light: "For the essence of light is its being manifest of itself, and so seen, and that it makes other things manifest, and is thus seen by"—see p. 7. Again, the style

of 'Abû-Jafar 'al-Khâzin, as indicated in an extract from one of the mss. of the Bodleian Library, given in Catal. Bibl. Bodl., ii. 261, as follows:

ا, "he aimed at brevity in the work, abridging the phraseology and diminishing the number of the figures, without removing doubt or doing away with obscurity," which refers to a commentary on Euclid, seems to us very like that of our author.

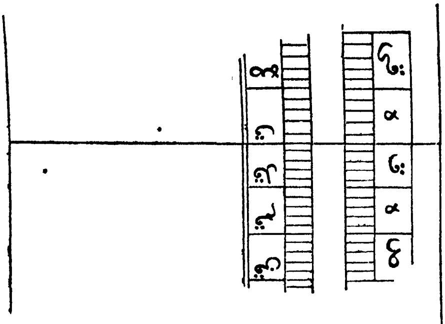
Upon the whole, we incline to believe that our author and 'Abû-Jafar 'al-Khâzin and the optician Alhazen, perhaps also D'Herbelot's Khazeni, are one and the same person. We venture, at least, to suggest this, for confirmation or refutation by farther research. We may here say that we have been in some doubt whether to read the name of our author 'al-Khâzin or 'al-Khâzinî, the Arabic ms. sent to us by M. Khanikoff, which gives the latter reading, not being decisive authority on this point. We beg our correspondent to settle the question by reference to the original ms. For the proposed identification, however, it is equally well to assume the name to be 'al-Khâzinî, inasmuch as, according to Risner, the author of the book on optics was called "Alhazen fil. Alhayzen," that is, 'al-Khâzin Bin 'al-Khâzin, to which 'al-Khâzinî, in the sense of "related to 'al-Khâzin," is equivalent.

4, p. 37. In reproducing this figure, we have struck out a point assumed in the original between *h* and *ṭ*, and made use of in the fifth theorem, because it is of no service, and only makes the figure inconsistent, and less applicable to the following theorems.

5, p. 39. It seems to us that the remark of our author here referred to is misinterpreted by M. Khanikoff. The former means simply to say that no interference with one another's motion is apparent in the case of the celestial spheres, while he neither affirms nor denies the principle of universal gravitation.

6, p. 42. The figure here given of the areometer of Pappus is considerably altered from that presented by M. Khanikoff. The latter occurs twice in the manuscript, once in the Arabic text, and once in the translation: the two forms are of somewhat different dimensions, and are quite inconsistent with one another with respect to the details of the graduation, which are moreover, in both, altogether inaccurate. Both, however, agree in offering, instead of a double scale, two separate scales, standing in a reversed position at a slight interval from one another. As it was impossible to reconcile such a figure with the directions given in the text, we have preferred to construct a new one, in accordance with our best understanding of those directions. In so doing, we have

been compelled to amend the text slightly as regards the lettered points referred to, as well as the lettering of the figure itself, inasmuch as the latter in the manuscript was so imperfect and inaccurate as to be unintelligible. For the purpose of showing the alteration we have made, we present herewith an exact copy of the portion of the manuscript figure about the equator of equilibrium. It will illustrate also the manner in which the numbering of the instrument is indicated (very inaccurately upon the left scale) in the figure.



7, p. 42. See the statement, on page 98, that the Arab physicists were accustomed to enchase silver points upon the right arm of the beam of the balance, for specific gravities; and the description of the balance on page 97. To graduate by round points seems to have been the mode among the Arabs.

8, p. 47. We have constructed this table anew, and have corrected at many points the sixtieths of our original: in some cases, the readings of the latter may have become corrupt; in most, there was probably a want of accuracy in the original constructor.

The readings of the manuscript which we have altered are as follows:

Line of Numbers.	*Parts.*	*Sixtieths.*	*Line of Numbers.*	*Parts.*	*Sixtieths.*
105	95	16	87	114	58
104	96	12	86	116	12
103	97	9	83	120	30
102	98	6	76	131	36
101	99	3	69	144	54
99	101	2	64	156	16
98	102	5	62	161	20
97	103	8	61	163	58
96	104		55	181	50
94	106	21	52	192	20
88	113	37			

There are also several cases in which we have retained the figures given by the manuscript, although not quite correct, when they differed by less than 1 from the true value. Thus, opposite the number 106, we find set down a remainder of 21 sixtieths, while the true remainder is 20.376, and, of course, 20 would have been more accurate.

9, p. 50. We alone are responsible for the translation of this section, our correspondent having left it untranslated. In the lettering of the first figure here introduced, we have so far deviated from our Arabic original as to substitute ج and م for خ and ش, respectively, in order to simplify the transcription.

10, p. 53. The meaning of this somewhat obscure statement is probably as follows. Two heavy bodies at opposite extremities of a lever act upon each other by their gravity to produce motion, and remain at rest only when their common centre of gravity is supported. The same is true of balls thrown into a spherical vase: they act upon each other by their gravity to produce motion, and they remain at rest only when their common centre of gravity is supported, that is, when it stands over the lowest point of the spherical surface.

11, p. 54. In our reproduction of this figure, we have reduced its size one half, improved the form of the "bowl," *f*, and given in the margin the explanations which in the original manuscript are written upon the figure itself, at the points where the letters of reference are placed.

12, p. 56. We have taken the liberty of slightly altering our correspondent's manuscript in order to insert the table here given, because the latter seemed to be so distinctly referred to upon page 78 that it was necessary to assume that the Arabic work originally contained it. M. Khanikoff gives the mean weight for bronze as 11 m., 2½ d.; but, considering the acknowledged corrupt state of the manuscript in this part, we have thought ourselves justified in amending the reading to 11 m., 2 d., since this value is required by that of the "result" derived from it for the succeeding table. In the table on p. 78, it will be noticed, bronze is omitted.

13, p. 63. 'Aḥmad 'at-Taifâshî, in his book on precious stones, ed. Raineri, page 10 of text, describes the yâḳût 'asmânjûnî as including "the cerulean, that which resembles lapis lazuli, the indigo-like, the collyrium-like, and the dusky"—by which may be intended, as the editor says (annott., p. 80), all sorts of sapphire and aqua marina.

14, p. 63. According to 'at-Taifâshî, page 13 of text, the raiḥânî, or basil-like, is a variety of the emerald, "of pale color, like the leaves of the basil;" the same authority defines the silḳî, or beet-like, as another variety of this mineral, "in color like the beet," that is, probably, like beet-leaves.

15, p. 64. In thus rendering the word البقراني, we conjecture it to be derived from البُقْرَة with the signification "circulus ungulæ bubulæ magnitudine," as given by Freytag. Raineri gives us another reading for this word, namely البقراوى, and explains it as possibly signifying *of Bukhârâ*—see text of 'at-Taifâshî, p. 35, and annott., p. 100—which, however, seems to be quite impossible. The Arab mineralogist's description of the species of onyx bearing this name is as follows: "البقراوى is a stone composed of three layers: a red layer, not transparent, followed by a white layer, also not transparent, next to which is a transparent, crystal-like layer. The best specimens are those of which the layers are even, whether thick or thin, which are free from roughness, and in which the contrast [of color] and its markings are plainly seen;" which corresponds to what Caesius, in his Mineralogia, Lugd., 1636, p. 569, says of the most precious sardonyx, thus: "Quæres tertiò quænam sit sardonyx omnium perfectissima. Respondeo esse illam quæ ita referat unguem humanum carni impositum ut simul habeat tres colores, inferiorem nigrum, medium candidum, supremum rubentem. . . . Nota autem, cum sardonyx est perfecta, hos tres colores esse debere impermixtos, id est, ut zona alba nihil habeat mixtum alieni coloris, et sic de nigrâ et purpureâ." But, if our reading البقراني is correct, and the derivation which we have suggested for the word is adopted, this species of onyx must have been so named from specimens with their layers of different colors intermingled, which the modern mineralogist would call by the name of agate rather than that of onyx. Perhaps, however, the reading should be البيقراني, from البَيْقُرَان, the name of a certain plant, which we have not identified. In this case, the name would be similar in its origin to "basil-like" and "beet-like," applied to varieties of the emerald, and appropriate for specimens of onyx with either distinct or intermingled layers, the veining of the mineral having nothing to do with its name.

16, p. 65. Caesius, Id., p. 520, says: "Dioscorides, Judaicus, inquit, lapis in Judæâ nascitur, figurâ glandis, eleganter et concinne confectus, lineis inter se æqualibus veluti torno factis," etc. Prof. J. D. Dana of Yale College, to whom we are indebted for the foregoing quotation, infers from this description that the Jews' stone was the olive-shaped head of the fossil encrinite. Ancient physicians dissolved it for a draught to cure gravel. 'Ibn-Baiṭâr, in his Mufridât, ed. Sontheimer, i. 285, speaks of it in the same terms as Caesius does.

17, p. 65. Probably a fossil. M. Khanikoff quotes the following from the Kâmûs: السرطان دابّة نهرية كثيرة النفع ... واما البحرى [illegible] فحيوان

متحجر, "The crab is a river-animal of great use ... on the other hand, the sea-crab is a petrified animal." One might ask the question, whether the latter was so called because found in the sea, or whether that name implies a belief that the sea once extended where afterwards was dry land, in accordance with modern geological discovery.

18, p. 66. In explanation of this term, our correspondent cites, from a Jaghatai Turkish translation of 'al-Ḳazwînî's 'Ajâ'ib 'al-Makhlûḳât, a passage which states that "the finest quality of glass was Pharaoh's glass, found in Egypt." The original Arabic gives no such statement under the head of glass. For an account of the translation referred to, see M. Khanikoff in the Bulletin Hist.-Phil. of the Imperial Academy of St. Petersburg, for Nov. 8, 1854 (Mélanges Asiatiques tirés du Bulletin etc., ii. 440–446).

19, p. 72. We have substituted this citation from the original Arabic of 'al-Ḳazwînî for a passage which our correspondent here quotes from the Jaghatai Turkish translation referred to above. The citation of M. Khanikoff, of which only the first sentence is recognizable in the Arabic, is as follows: "Khuwârazm is a vast, extensive, and populous province. There is in it a city named Jurjânîyah. . . . The cold there is so intense that a man's face freezes upon his pillow; the trees split by reason of the cold; the ground cracks; and no one is able to go on horseback. One of its frontiers is Khurâsân, the other Mâwarâlnahr. The river Amû [the Jaiḥûn], freezes there, and the ice extends from there to the little sea. In the spring, the waters of the little sea mingle with the water of the Amû, and come to Khuwârazm;" on which our correspondent observes: "If I am not mistaken, this passage, which establishes with certainty that the waters of the Amû reached the Sea of Aral only during the spring freshets, is unique; and it points out to us, perhaps, the way in which the change of its mouth originally took place."

By way of illustration of 'al-Ḳazwînî's description of the lower course of the Oxus, it may not be amiss to cite what Burnes says of it in his Travels into Bokhara, iii. 162. Having spoken of its winding among mountains till it reaches the vicinity of Balkh, Burnes says: "It here enters upon the desert by a course nearly N. W., fertilizes a limited tract of about a mile on either side, till it reaches the territories of Orgunje or Khiva, the ancient Kharasm, where it is more widely spread by art, and is then lost in the sea of Aral. In the latter part of its course, so great is the body of water drawn for the purposes of irrigation, and so numerous are the divisions of its branches, that it forms a swampy delta, overgrown with reeds and aquatic plants, impervious to the husbandman, and incapable of being rendered useful to man, from its unvarying humidity."

20, p. 73. These terms are explained by a passage appended to this section in the translation of our correspondent, for which he has omitted to give the Arabic text. We quote the translation here:

"All the substances mentioned in this section sink in water if the weight of their equivalent volume of water is less than 2400 ṭassûjs, and float if that weight equals or exceeds the same number.

End of the first section."

21, p. 74. It might be suspected that the word العاج, "ivory," should rather be العلك, "resin," this being one of the substances of which, in the opening of the chapter, our author proposed to give the water-equivalent. As, however, the specific gravity derived from the equivalent given is 1.64, and that of the common resins is only about 1. to 1.1, it is perhaps easier to assume that resin has been accidentally omitted from the table.

22, p. 76. This process can be made clearer by an algebraic method of statement. Let $C =$ a cubit, $c =$ the length of a side of the cube measured, and $t =$ the diameter of the silver thread: then $C = 4c + \frac{1}{5}(c - \frac{1}{5}c)$: but $c = 259\,t$; therefore, $C = 1082\frac{2}{45}t$. For the fraction $\frac{2}{45}$ our author now substitutes $\frac{3}{60}$, because, as appears from their use in the table on p. 46, sixtieths are to him what decimals are to us, and $\frac{3}{60}$ are nearly equivalent to $\frac{2}{45}$. C, then, equals $\frac{64{,}923}{60}$. Substituting, in the proportion $c^3 : C^3 :: 9415$ ṭassûjs : the weight in ṭassûjs of a cubic cubit of water, the numerical value of the first two terms, we have $17{,}373{,}979 : \frac{273{,}650{,}180{,}698{,}467}{216{,}000} :: 9415 : 686{,}535.53$. If the original fraction $\frac{2}{45}$ had been retained, the result would have been 686,525 ṭassûjs.

The question naturally arises, why 'Abû-r-Raiḥân had recourse to the use of the silver thread in making this experiment. It is evident that, when once we have the value of C expressed in terms of c, we may reject t altogether, and obtain the same result as before by the much less laborious reduction of the proportion $1 : \frac{6{,}644{,}672}{91{,}125}\left(\text{i. e. } 1^3 : \left(\frac{188}{45}\right)^3\right)$ $:: 9415 : 686{,}525$. This fact, however, our author does not seem to have noticed. Was the silver thread, then, employed merely as a mechanical device for facilitating an exact comparison of C and c? This seems by no means impossible, since, after finding the first remainder, and perceiving it to be equal to 46 diameters of the thread, the relation of that remainder to the side of the cube would be at once determined, without going through with the two additional, and more delicate,

measurements otherwise required, and exposing the process to the chances of error to which they would give rise. We may also, perhaps, suppose that the original experimenter was actuated by a desire to furnish to any who might repeat the experiment after him the means of comparing their results with his, and that, in the want of any exact standard of measurement (since the measures may have varied in different localities not less than the weights are shown to have done by the table upon p. 81), he devised this method of the fine silver thread with the view of providing, in this case, such a standard.

23, p. 78. We have introduced into this table a number of emendations, which were imperatively called for. All the data for constructing it had been given before, in the table of water-equivalents upon p. 56, and the determination of the weight of the cubit cube of water just made, and we had only to work out, in the case of each metal, the proportion: the water equivalent of the metal, in tassûjs : 2400 : : 686,535.53 : the weight of a cubic cubit of the metal. For mercury, the manuscript gives erroneously 387,973 m.; for silver, 294,607 m.; this would be the correct result if the calculator, by a slip of the pencil, had taken 686,435.53 as the third term of his proportion. For tin, the Arabic gives 209,300; but, as the translation presents the correct number, the former must be an error of M. Khanikoff's copyist. The column of 'istârs is left unfilled in the Arabic manuscript; our correspondent had supplied the deficiency, but incorrectly in the majority of cases (all excepting mercury, silver, and iron). It admitted, indeed, of some question how many 'istârs our author reckoned to the mann: we adopted 40, both because that seems to be the more usual valuation, and because, by assuming it, the column of fractions of 'istârs comes out in most instances quite correct: only in the case of lead, the manuscript gives a remainder of $\frac{1}{3}+\frac{1}{4}$; in that of iron, $\frac{1}{5}$; of tin, $\frac{1}{3}+\frac{1}{5}$. The same valuation of the 'istâr was assumed in correcting the reading at the bottom of p. 77, where the great corruption of the whole passage, and the absurdity of its unamended readings, was very evident.

24, p. 82. Considering the uncertain character of even the main elements entering into this calculation, and that its result cannot accordingly be otherwise than approximate only, it seems to us that our correspondent might have spared himself the labor of calculating the effects of an assumed difference of temperature, pressure, and gravity: the modifications which are thus introduced lie far within the limits of probable error from other sources; and, in fact, had these modifying circumstances been left out of the account, a result would have been arrived at nearer to the value which M. Khanikoff finally adopts for

cubit than that which is actually obtained by his process. The value $c = 500$ mm., namely, supposes $\frac{c^3}{m^3} = .1250$; the actual value of the latter quotient, after modification of m^3, is .1291; before modification, .1287. We have not, therefore, in this instance, been at the pains of verifying either the formulas or the calculations of our correspondent.

25, p. 86. In reproducing the figure here given by our correspondent, we have reduced its dimensions one-third, without other alteration.

26, p. 86. This figure also is reduced one-third from that given in M. Khanikoff's manuscript.

27, p. 87. We have here followed our correspondent in giving only the original term, not being sure enough of its precise signification to venture to translate it, though we think it might be rendered "table of plane projections," or "planisphere." The connection shows that it denotes some astronomical instrument; and as well for this reason as because عرض, and not صفيحة, means "latitude," besides that زيج is not a plural, Casiri is wrong in translating كتاب زيج الصفايح, in a passage quoted from him on p. 115, as he does, by "Liber Tabularum Latitudinum."

28, p. 88. This figure is an exact copy of that given by M. Khanikoff, except that it is reduced to one-third its original size. Its insufficiency to explain the construction and adjustment of the parts which it represents is palpable. For farther explanation see note **33**.

29, p. 90. Our two diagrams on pp. 89, 91, though faithfully representing their originals, are, for convenience, made to differ from them in dimensions.

30, p. 90. Literally "the *point* going downward," implying the conception of a concentration of the weight of a body in its centre of gravity.

31, p. 94. We suppose the centre of gravity spoken of under the head of "Determination relative to the Beam connected with the Tongue," in this table, to be the common centre of gravity of the tongue and beam united. This seems to us to be indicated both by the reading of the Arabic text of the table, as it came to us, and by the suppositions, respecting the connection of the tongue and beam, considered in the extract which precedes it. But some changes of reading were required to make the table correct. The following fragment shows what are the

specifications of the text which we received, in those places where we have made changes.

<table>
<tr><th colspan="6">Determination relative to the Beam connected with the Tongue,</th></tr>
<tr><th rowspan="2">. . . .</th><th colspan="2">. . . . . . [the Axis being] below the C.</th><th colspan="3">. . . . . . [the Axis being]</th></tr>
<tr><th colspan="2"></th><th colspan="2">at the C. of Grav.</th><th>above the C.</th></tr>
<tr><td></td><td colspan="2"></td><td colspan="2">Revers.</td><td></td></tr>
<tr><td rowspan="2"></td><td colspan="2">Revers.</td><td colspan="2" rowspan="2"></td><td rowspan="2">Equip.</td></tr>
<tr><td>Nec. Parall.</td><td>Equip.</td></tr>
<tr><td rowspan="2"></td><td colspan="2" rowspan="2">Equip.</td><td colspan="2">Revers.</td><td rowspan="2"></td></tr>
<tr><td>Nec. Parall.</td><td>Equip.</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
</table>

On the supposition that the centre spoken of is the centre of gravity of the beam, many more alterations would have been necessary.

32, p. 95. Our correspondent did not translate this passage, so that we alone are responsible for the description of the winged bowl. We were about to offer some conjectures which seem naturally to suggest themselves in explanation of the peculiarities of this bowl; but, since we have so little ground for certainty in regard to it, we prefer to waive the subject. It will be noticed that our two drawings of the bowl are dissimilar, and that the one which is given in the figure of the whole balance is the least conformed to the description of our author.

33, p. 96. The figure of the Balance of Wisdom given here is as exact a copy as possible of the figure in M. Khanikoff's manuscript, excepting that it is reduced in dimensions one-third. Where the beam is crossed by the two slanting pieces, the shading of the one and the graduation of the other are both continued without a break, so that it is impossible to decide by the figure which is regarded as lying upon the other. This ambiguity the engraver has reproduced as well as he could. It is impossible, with no more light than we have on the subject at present, to determine the use and connection of all the parts of the balance here represented. There is even an apparent inconsistency between the figure on p. 88 and the drawing of the same part here given. The two drawings are, indeed, quite insufficient of themselves to explain the construction of the instrument. But what is especially to be regretted is that M. Khanikoff has omitted to cite our author's description of the axis and its pivots, or to give us so much as a hint of the mode in which the beam was held up. Yet, as the case now stands, a definition in the Ḳâmûs of the use of the two sloping pieces represented in our drawings on opposite sides of the tongue of the balance, enables us to make out

ome of the leading parts of the construction. Those sloping pieces re called by the name of الفياران, substituted for the ms. reading, الفنارير, which makes no sense. Of this term the Ṣiḥâḥ says: والفياران اللذان يكشفان لسان الميزان, "the فياران are those two ieces which show the tongue of the balance." But the Ḳâmûs is more efinite, and says: والفياران بالكسر حديدتان تكتنفان لسان الميزان وفرّته عملت له فيارين وانه لفيور كعبور, "الفياران with kasr signifies wo pieces of iron which enclose the tongue of the balance, and فرّته ignifies that I have made for the tongue such two pieces, and that it is فيّر, which is equivalent to saying that it has stops put to it." Plainly, hen, the tongue of the balance moved from one to the other of the wo pieces of iron thus described, and must have been in the same plane vith them; and, since the middle vertical line of the tongue would of ourse range with that of its frame, the axis must have been bisected, ongitudinally, by the same line. Thus, then, we are able to conjecture vhat the two parallel pieces in our larger drawing are intended to represent. They may be the supports of the two ends of the axis; and he inconsistency between this drawing and the one on p. 88, which we ave alluded to, may be only apparent. For above the supports of the xis, and between the lower ends of the فياران, there must have been n opening to allow the tongue to play within its prescribed field of notion—whether the frame of the tongue rested upon one of the supports of the axis, as our large drawing seems to show, or stood between he two. In accordance with this view, we regard the figure on p. 88 s representing only the tongue and its frame, and the bends at the bottom of it as bends of the فياران.

Both of the parallel pieces are represented as if indefinitely prolonged towards the right, and, though this may be a mere inaccuracy of drawing, it is not unlikely that they were attached, in some way, to a fixed upright support, on that side, for the sake of giving a more stable position to the axis.

It remains for us to state the grounds on which we have assigned to he word العريضة the signification of "front-piece." This term is inscribed, in both of our drawings, on the top-piece of the frame of the ongue, and also, in the larger one, along the nearer of the two parallel pieces, at *e*: so that one might think that two different parts of the structure were called by the same name, on account of something in common between them; or else that it was applied to the whole structure consisting of the frame of the tongue and the two parallels. But we believe he inscription of this word along one of the parallels to be simply a nisplacement, العريضة being there the first word of a sentence of ex-

planation which is finished under the beam on the left. We therefore regard this term as appropriated to the frame of the tongue. The etymology and form of the word itself give it the meaning of "that which fronts;" but, unfortunately, neither the Ṣiḥâḥ, nor the Ḳâmûs, nor any European dictionary of the Arabic which we have been able to consult, defines it in its application to the balance.

In making these suggestions we have been aided by a scientific friend, Rev. C. S. Lyman of New Haven, to whom we desire to express our obligations.

34, p. 97. So called, we may suppose, from their being obtained by calculation.

35, p. 98. To explain this formula,

Let W be the weight in mithḳâls of a compound body (gold and silver);
x the weight in mithḳâls of the silver contained in it;
$w-x$ " " the gold " "

Then $s.gr.$ (the spec. grav. of the compound) $=W$ (its weight in air) divided by the weight of water which it displaces. But if d' and d'' are the specific gravities of gold and silver, the water displaced by $(W-x)$ mithḳâls of gold will weigh $(W-x)\div d'$; that displaced by x mithḳâls of silver, $x\div d''$. Hence

$$\frac{W}{\frac{W-x}{d}+\frac{x}{d''}}=s.gr.;\ \text{or}\ \frac{W}{r.}=\left(\frac{W-x}{d'}+\frac{x}{d''}\right)$$

By transposition, $\frac{x}{d'}-\frac{x}{d''}=\frac{W}{d'}-\frac{W}{s.gr.}$; whence $x=W\frac{\frac{1}{d'}-\frac{1}{s.gr.}}{\frac{1}{d'}-\frac{1}{d''}}$

36, p. 105. See note **5**.

We have just received, in the Journal Asiatique, v[e] Série, xi., 1858, a paper by M. Clément-Mullet, which exhibits tables of water-equivalents, water-weights, weights of equal volumes of substances, and specific gravities, derived from 'Abu-r-Raiḥân, through the medium of the Âyîn-i-Akbari. The foregoing article will be found to correct and supplement the statements of M. Clément-Mullet's paper, in many particulars, as, indeed, it rests upon a much wider basis; and we feel sure of its meeting with a cordial welcome from the French savant, whose interest in the subject has been manifested by valuable contributions to

our knowledge of the sciences of the East. It may not be amiss, then, to indicate here some errors in the tabular statements of the paper referred to.

Since the sum of the water-equivalent and the corresponding water-weight must in every instance be 100 mithkâls, the water-equivalents given for mercury, silver, and emerald require the water-weights of these substances, respectively, to be 92.3.3, 90.1.3, and 63.4, instead of 92.0.3, 90.1, and 68.4, as stated.

The water-equivalent of copper is stated to be 11.3, whereas our author gives us 11.3.1: but the weight assigned to the equal volume of copper also differs from our author's statement, being 45.4 instead of 45.3. This brings us to a point of greater apparent disagreement between 'Abu-r-Raiḥân and 'al-Khâzinî, the columns of weights of equal volumes. Now, as these weights must in every case be derived from the data furnished by the preceding columns, by a rule which our author gives, although it is nowhere presented in the quotation from the Âyîn-'Akbari, we must be allowed to mention the following as errors under this head, viz: mercury 71.1.3 for 71.1.1, silver 53.5.1 for 54.0.2, bronze 46.1.2 for 46.2, copper 45.4 for 45.3, brass 44.5.1 for 45, tin 38.0.3 for 38.2.2; ruby (or red hyacinth) 97.1.1 for 97.0.3, ruby balai (if the same as ruby of Badakhshân) 90.2.2 for 90.2.3, emerald 69.2.3 for 69.3, cornelian 64.3.3 for 64.4.2.

But, if we examine the statement of the weights of equal volumes in Gladwin's translation of the Âyîn-'Akbari, we shall find that this may be so interpreted as to come into exact coincidence with our author's statement, in all but one of the cases here in question. For, supposing that Gladwin's figure 8, wherever it occurs in the fractional columns, comes from a wrong reading of ح for غ=0, agreeably to a suggestion of M. Clément-Mullet, or is a mistake for 3=ج; and farther, that Gladwin's figure 5, given for ṭassûjs in the weight of the equal volume of brass, is a mis-reading of ٥ for ٠; and lastly, supposing Gladwin's mithkâl-figure 4 in 94.0.3 for amethyst (or red hyacinth) to be a mis-reading of د for ر—suppositions which derive support from an extended comparison of the tables given by Gladwin with the corresponding tables of the foregoing article—we obtain the following weights of equal volumes from the English translation of the Âyîn-'Akbari, viz: mercury 71.1.1, silver 54.0.3 (instead of the true number 54.0.2), bronze 46.2, copper 45.3, brass 45; amethyst (or red hyacinth) 97.0.3, ruby (probably ruby of Badakhshân) 90.2.3, emerald 69.3, cornelian 64.4.2.

We have thus far passed over pearl and lapis lazuli, because the weights which the French savant gives to equal volumes of these substances show a double error—their respective numbers being transposed, while,

at the same time, the number truly belonging to pearl is 65.3.2, and not 65.4. This transposition, though not the wrong number for pearl, occurs also in Gladwin's translation; and in correspondence with it, in both the French and the English presentation of 'Abu-r-Raiḥân's results, the water-equivalents of pearl and lapis lazuli are transposed, that of pearl being 37.1 for 38.3, and that of lapis lazuli 38.3 for 37.1. If, however, the specific gravity of pearl was supposed by the Arabs to be less than that of lapis lazuli, agreeably to our table, its water-equivalent must have been rated the highest. It is scarcely to be believed that any accidental difference of quality in the pearls of 'Abu-r-Raiḥân from those experimented upon by 'al-Khâzinî, could have led the former to a water-equivalent for pearl precisely the same as that which the latter found for lapis lazuli.

Again, M. Clément-Mullet's list of specific gravities deviates in several instances from the results which should have been brought out by the water-equivalents given, as: silver 10.35 for 10.30, copper 8.70 for 8.69 (according to 'al-Khâzinî, 8.66), etc. The specific gravity obtained for amber, 2.53, while agreeing with the water-equivalent assigned to it, 39.3, so far exceeds the modern valuation as to occasion a remark by the French savant: but our author gives it a much higher water-equivalent, namely 118, and consequently a much lower specific gravity, namely .85. It would seem, then, altogether likely that not amber, but some other substance, was here referred to by 'Abu-r-Raiḥân; perhaps coral, which is given by 'al-Khâzinî in the same connection.

These remarks cover all the substances mentioned by 'Abu-r-Raiḥân, excepting gold, lead, iron, celestial hyacinth, and crystal—in regard to all of which there is no disagreement between him and 'al-Khâzinî—so that, besides their purpose in the way of criticism, they serve to show an almost entire identity between 'Abu-r-Raiḥân's tables, so far as they go, and those of our author. The course pursued by the latter, in his tabular statements, would seem to have been to adopt, with some correction, the results obtained by the earlier philosopher—to whom, it will be remembered, he frequently refers as an authority—and to add to them by experiments of his own.